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Great Lakes Oil-In-Ice Demonstration 3 Final Report

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15. Supplementary Notes

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16. Abstract (MAXIMUM 200 WORDS)

This report describes the third season continuance of an effort by the Coast Guard, in collaboration with other Federal, state, and local agencies, private industry, and international interested parties, to gain practical knowledge and field experience in the coordination and operation of equipment, and the exploration of techniques applicable to the recovery of oil spills in ice-infested waters. The effort explored and demonstrated two commercial oil skimmers, a boom, fire cannon herding equipment, ice detecting radar, remotely operated vehicle (ROV), and autonomous underwater vehicle (AUV) in rubble and sheet ice conditions during February 2013 in the Straits of Mackinac on the Great Lakes in northern Michigan. The exercise produced many valuable 'lessons learned' that are applicable to ice-infested waters within the continental United States and in the Arctic waters of Alaska.

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- National Oceanic and Atmospheric Administration (NOAA)
- Michigan Department of Environmental Quality (DEQ) Water Resources
- Salvation Army

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EXECUTIVE SUMMARY

This report has been revised to include a description of the AUV data that was collected on Day 2 of the demonstration.

The United States Coast Guard (USCG), Environmental Protection Agency (EPA), local states, and the Canadian Coast Guard (CCG) routinely respond to oil spills during the winter months in the Great Lakes areas. Increasing vessel and barge traffic raises the risk for additional accidental discharges. While oil recovery issues have come to the attention of responders, researchers, and other stakeholders, work continues on improving response capabilities under possible harsh conditions.

Cold climate conditions, including the presence of ice, complicate a response effort. Studies investigating the behavior of oil, current capabilities, and data gaps over the past two decades have helped increase our understanding of processes that take place during a spill. In spite of this, there is a need for more research to improve response capabilities in these conditions.

This effort is the third in a series of planned on-water demonstrations to assess current spill response capabilities. It attempts to identify operational performance gaps and acquire lessons learned. The design of this project is to leverage the needs and requirements of both Arctic and Great Lakes environments in order to identify equipment and techniques that would work in both locations to recover spilled oil.

This report centers on a 4-day field demonstration during which the Coast Guard and a select group of local Oil Spill Response Organizations (OSROs) had the opportunity to demonstrate selected equipment with potential for use in ice-infested waters. As part of the goal of collecting information on equipment staging and operation, requirements for offloading, set-up, and deployment as well as operations were noted. Several apparatus were deployed and tested over the 2-day ‘on the water’ portion of the demonstration.

The “practice” fire boom was deployed from the deck of the barge and then recovered by a crane in sections. Two tugboats were able to successfully capture and tow a quantity of ice broken from the ice pack. To maintain ice in the ‘pocket’ of the boom, towing speed had to be kept to a minimum. The ability of the tugboat to operate at a slow speed makes it ideal for the process as opposed to a vessel that must continually clutch its prop in and out to limit headway. Any type of boom used with this tactic must be extremely robust and should be deployed and retrieved in open water.

A bucket skimmer was operated from fixed mounts on the deck of the barge. It was demonstrated in conjunction with herding techniques. The tactic selected for this system would depend upon the location of the skimmer on the barge.

A self-contained fire monitor was demonstrated as a means of guiding or directing an oil spill surrogate consisting of peat moss and oranges towards the bucket skimmer on the barge deck. While slow and a bit tedious, this method appeared to work, but moving larger pieces of plate ice with the water jet was difficult. This concept appeared to function well as the water jet from the fire monitor had a wide range of impact. For this demonstration, the fire monitor was stern-mounted. Bow-mounting the water cannon may lead to easier positioning and handling of the vessel. Use of this technique along an ice edge would be beneficial.

The DESMI Helix skimmer was successfully deployed using the Coast Guard Cutter (CGC) Hollyhock’s bow-mounted 750-pound (lb) crane block. The skimmer was demonstrated in open pockets of water

surrounded by rubble and sheet ice. The Helix fittings, hoses, and moving parts could be better ruggedized or armored for protection from impact by rubble ice. A sling or festoon configuration might help suspend and support the hoses from contact and damage from floating ice.

The AUV malfunctioned the first day and sunk to the bottom. The ROV was used to recover it during a 4 hour search. On the second day, the AUV performed an abbreviated demonstration of its ability to independently operate and collect sensor data under open water and beneath an ice sheet.

The ROV was deployed but without the ultraviolet (UV) fluorometer which had suffered pre-deployment damage. The ROV demonstrated great potential as an under-ice sensor platform and mission flexibility through its ad-hoc reconfiguration for search and recovery of the disabled AUV. It was deemed too small to perform sophisticated missions using precision sensors without additional stabilization capability. Use of sophisticated sensors would require a more stable platform using either software to configure the data collected or a larger ROV.

The Rutter oil spill detection and ice detection radar clearly displayed areas of open water as well as a variety of lake ice types (e.g., solid plate, rubble, and windrow features) that were not discernible on the vessel's navigation radar. Because there was no actual oil spill, no demonstration of the system's ability to detect and identify oil was performed.

The Aerostat IC balloon, equipped with remotely-controlled electro-optical (EO) visible light and infrared (IR) real-time video cameras had launch difficulties on the first day. Wind turbulence and eddies around nearby barge deck structures inhibited the launch. On the second day, equipment was rearranged on the barge deck eliminating the turbulence and the launch was successful. Both the remote-control tilt/pan/zoom real-time EO and IR sensors provided excellent situational awareness of the operational scene, especially to the command center about 4 miles away.

The deployed equipment exhibited varying utility for spill clean-up under various ice conditions. Performance of each piece of equipment is dependent on ice, wind, and weather conditions. All were successfully staged and deployed. Several valuable 'lessons learned' regarding each of the deployed devices, vessels, tactics, and mission deployment were documented and their impact on spill recovery work was identified. Continued collaborative field demonstrations in the Great Lakes and Alaskan Arctic under more severe weather and ice conditions, with continued use of an environmentally benign oil simulant, were recommended.

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LIST OF ACRONYMS

ADCP	Acoustic Doppler Current Profiler
AGL	Above ground level
AIS	Automatic Identification System
AUV	Autonomous underwater vehicle
CCG	Canadian Coast Guard
CG	Coast Guard
CGC	Coast Guard Cutter
CONEX	Container Express
CTD	Conductivity/temperature/depth
D17	District 17
D9	District 9
DEQ	[Michigan] Department of Environmental Quality
DRAT	District Response Advisory Team
E	East
EO	Electro-optical
EPA	Environmental Protection Agency
EST	Eastern Standard Time
F	Fahrenheit
FOSC	Federal On-Scene Coordinator
GHz	Gigahertz
gpm	Gallons per minute
GPS	Global Positioning System
HAZMAT	Hazardous material
hp	Horsepower
hr	Hour
Hz	Hertz
ICC	Incident Command Center
ICS	Incident Command System
IR	Infrared
ISB	In-situ burning
kg	Kilogram
kHz	Kilohertz
km/h	Kilometers per hour
kNm	Kilo Newton-meter
kt	knot
kVA	Kilovoltampere
kW	Kilowatt
lb	pound
LF	Laser fluorometer
LRB	Lamor Oil Recovery Bucket

LIST OF ACRONYMS (CONTINUED)

m	Meter
m^3/hr	cubic meters per hour
MAWP	Maximum allowable working pressure
mm	Millimeter
mph	Miles per hour
MSU	Marine Safety Unit
N/A	Not available
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration
NSF	National Strike Force
NSFCC	National Strike Force Coordination Center
NW	Northwest
OIC	Officer in Charge
OSD	Oil Spill Detection
OSHA	Occupational Safety & Health Administration
OSRO	Oil Spill Response Organization
PAO	Public Affairs Officer
psi	Pounds per square inch
RDC	Research & Development Center
ROV	Remotely operated vehicle
rpm	Revolutions per minute
RSD	Radar System Data
SAIC	Science Applications International Corporation
SE	Southeast
shp	Shaft horsepower
SSM	Sector Sault Ste. Marie
T/V	Tugboat vessel
TBD	To be determined
tm	Tons metric
TRACEN	Training Center
TTM	Tracked Target Message
U.S.	United States
UHF	Ultra high frequency
USCG	United States Coast Guard
UV	Ultraviolet
VAC	Volts alternating current
VDC	Volts direct current
VHF	Very high frequency
WHOI	Woods Hole Oceanographic Institute
WLB	Coast Guard Buoy Tender
µPa	Micropascal

1 BACKGROUND

This effort was performed under Project 4701, Response to Oil in Ice. The Coast Guard (CG) needs to improve the methodologies used to minimize the damage to the environment caused by spilled oil in extreme cold either in the Arctic Region or the Northern states. The objective of this demonstration was to evaluate response capabilities in cold weather by leveraging CG and other local assets in the Great Lakes before conducting a more complex demonstration in Alaska. This is the third in a series of demonstrations, the first which occurred in Sault Ste. Marie, MI in April, 2011 (Reference 1) and the second in St. Ignace, MI in January 2012 (Reference 2).

There are multiple commercial, state, and international manuals which describe tactics that can be used in cold weather. These recommendations change depending upon weather conditions, ice conditions and the oil spill size, weathering, and movement. They are generally written for solid ice when personnel and equipment can be placed safely on the ice, and broken ice which cannot support personnel and equipment. There is also a category of open water but operating when ice is serving as a barrier and the oil is sitting against it. The focus of this effort is to identify tactics that can be safely used in broken ice and near the ice edge by CG vessels and supporting local Oil Spill Response Organizations (OSROs).

2 INTRODUCTION AND OBJECTIVES

In the northern climates of the United States (U.S.), the CG, Environmental Protection Agency (EPA), local states, and the Canadian Coast Guard (CCG) routinely respond to oil spills during the winter months. Currently, the majority of the spills are tank leaks and gasoline truck accidents that may occur near waterways and thus the spilled oil can reach navigable waters such as harbors and rivers. While the oil recovery issues have been generally addressed, reduced ice during some seasons may increase vessel and barge traffic. This factor, along with an aging pipeline infrastructure, increases the potential for accidental discharges. To address these concerns, and to take advantage of emerging oil recovery technologies, northern climate regions are re-evaluating the equipment and techniques that are available. Parallel efforts have been made in District 17 (D17) to increase the spill response capabilities off the North Slope of Alaska in anticipation of increased exploration, drilling, and shipping.

This effort was an on-water exercise demonstrating current capabilities and an attempt to identify operational performance gaps. This demonstration was built on the previous knowledge base and lessons learned, as well as taking advantage of new response developments. This project was designed to identify equipment and techniques that would work in both Arctic and Great Lakes environments. This report documents the demonstration in chronological order and then summarizes all of the observations and lessons learned.

This demonstration was comprised of a multi-day field exercise that included exploration and demonstration of tactics for oil recovery operations in frigid open water, under sheet ice, and in and among broken ice. The demonstration was staged out of the docking pier used by the Coast Guard Cutter (CGC) Biscayne Bay, right next to CG Station St. Ignace near the Straits of Mackinac, MI. See APPENDIX A for area maps and aerial photos of Station St. Ignace. During the demonstration, the US Coast Guard (USCG) and a select group of OSROs demonstrated the ability of various types of spill response equipment to recover an oil surrogate (e.g., peat moss, oranges) from ice-infested water. APPENDIX B describes the equipment involved in the exercise. APPENDIX C provides the manufacturers' websites where the literature and brochures for the specific equipment used in this demonstration can be found.

There were several vessels involved in the demonstration. The CG provided the CGC Hollyhock, a buoy tender (Coast Guard Buoy Tender (WLB)) with ice-breaking capabilities. This vessel's primary objectives were (1) to deploy a DESMI Helix skimming system, an autonomous underwater vehicle (AUV), a remotely operated vehicle (ROV) with two sonars and a laser fluorometer (LF), a Rutter oil and ice detection radar system, and (2) to develop operational procedures for use of a barge. The other vessels were commercial tugboats which deployed commercial responders and their equipment including that needed for herding and towing a fire boom. A barge was employed as a staging and launch platform for the Aerostat IC balloon with an electro-optical (EO) and infrared (IR) real-time video. It was also the platform for containment boom deployment and recovery, and for bucket skimmer operation. The barge has a crane onboard to deploy and move equipment. See APPENDIX D for vessel details.

Following each equipment deployment, there was a limited "hot wash" session among the teams to assess performance and collect lessons learned. Both days of the demonstration took longer than anticipated, the first day lasting until 1930 due to the search for a missing AUV and the second lasting until 1900 due to the ice conditions. So the planned full group daily sessions did not occur. A summary meeting addressing the full demonstration was held on the last day.

Additional objectives for this demonstration involved integrating an Incident Command System (ICS)

- Objective 1: Safely deploy oil spill detection and response equipment in ice-covered waters.
- Objective 2: Work with equipment and vessel contractors to ensure the appropriate tools, equipment, and personnel can provide the service.
- Objective 3: Determine operating procedures for future response operations.
- Objective 4: Train support personnel in the deployment of all equipment.
- Objective 5: Identify training areas, communication needs, and test the equipment and capabilities.
- Objective 6: Deploy ICS and develop structure for future execution.
- Objective 7: Provide recommendations in all aspects of the demonstration including tactics, execution, etc. based on lessons learned.

2.1 Demonstration Participants

See APPENDIX E for participant names, organizations, and contact numbers.

- CG Research & Development Center (RDC)
- CG District 9 (D9)
- Sector Sault Ste. Marie (SSM)
- CG National Strike Force (NSF)
- CG D17
- CG Training Center (TRACEN), Yorktown
- National Oceanic and Atmospheric Administration (NOAA)
- Science Applications International Corporation (SAIC)
- Observers
  - Michigan Department of Environmental Quality (DEQ)
  - U.S. EPA
  - Enbridge Pipeline
  - NOAA Thunder Bay National Marine Sanctuary
  - BPXA from Alaska

- Alpena Community College
- CG Marine Safety Unit (MSU) Duluth, MN

2.2 Demonstration Concept

This demonstration focused on conducting simulated oil recovery from ice-infested waters. The material recovered consisted of the environmentally benign surrogate peat moss and oranges deployed by CGC Hollyhock and one of the two U.S. registry tugboats. See APPENDIX F for the environmental letter of permission. The ability to recover the material in adverse cold-weather conditions was demonstrated from shipboard platforms in brash/rubble ice and among sheet ice.

2.3 Planning of Demonstration

A working group composed of representatives from RDC, D9, the NSF Coordination Center (NSFCC), NOAA, and SSM held periodic teleconferences starting in the Fall of 2012. The CGC Hollyhock (WLB-214) was assigned. Contracts were issued for two tugs and a barge to deploy response equipment, a local OSRO to supply the equipment, and a crane and forklift service. Permission was requested of the Michigan DEQ and approval given for use of the surrogates (oranges and peat moss) to simulate spilled oil. The pier where CGC Biscayne Bay normally ties up was the staging and loadout area. Two types of skimmers, a fire boom, Aerostat IC balloon, Rutter ice- and oil spill-detecting radar, an instrumented AUV, and an instrumented ROV were selected for demonstration. The Salvation Army was contacted and graciously provided a pier-side warming shelter, hot drinks, snacks, and box lunches for the participants.

2.4 Demonstration Schedule

Table 1 contains the high-level schedule for the field tests.

Table 1. High-level schedule for field tests.

Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
2/15/13	**2/16/13**	**2/17/13**	**2/18/13**	**2/19/13**	**2/20/13**	**2/21/13**	**2/22/13**	**2/23/13**
Organizing teleconference	N/A	Travel	Travel Vessels Arrive Set up ICS	Training/ Loadout/	Exercise Day 1	Exercise Day 2	Tear-down/ Pack Out	Travel

2.5 Test Conditions (Weather and Ice)

Table 2 shows the test conditions under which this test was conducted.

Table 2. Test conditions: weather and ice.

Loadout Day: Tuesday, 19 February 2013	
Air Temperature:	minimum 17 ° Fahrenheit (F); maximum 35 °F
Wind:	10 – 15 knots (kts), shifting to northwest (NW)
Maximum Wind Gusts:	35 kts
Precipitation:	3”-7” blowing snow, low visibility
Day 1: Wednesday, 20 February 2013	
Air Temperature:	minimum 6 °F; maximum 15 °F
Wind:	10 kts to 15 kts, generally northwest (NW)
Maximum Wind Gusts:	not available (N/A) miles per hour (mph)
Precipitation:	trace snow
Seas:	calm
Ice Conditions:	4”-12” of broken ice, broken plate and pancake ice. Open water in the immediate vicinity of the Mackinac Narrows Bridge
Day 2: Thursday, 21 February 2013	
Air Temperature:	minimum 4 °F; maximum 27 °F
Wind:	3 kts to 7 kts, generally southeast (SE)
Maximum Wind Gusts:	not available (N/A) mph
Precipitation:	0.0”
Seas:	calm
Ice Conditions:	New ice growth over the prior night with 100% loose ice west of the bridge
Un-load Day: Friday, 22 February 2013	
Air Temperature:	minimum 14 °F; maximum 27 °F
Wind:	13 mph to 21 mph, generally east (E)
Maximum Wind Gusts:	32 mph
Precipitation:	trace, blowing snow

3 THE DEMONSTRATION

3.1 Planning

The following planning occurred.

- Pre-demonstration meetings
  - Telephone conference calls were held, typically on a bi-weekly basis, to permit efficient communications, planning, coordination, and exchange of information among all participants.
- Federal Government inter-agency coordination
  - This was also performed through the planning meetings. Specific topics, such as NOAA's trajectory modeling support, were coordinated directly and discussed during the planning meetings.
- State and municipal coordination
  - This was also done through the planning meetings. Specific topics were coordinated directly and discussed during the planning meetings.
- Private sector coordination (equipment suppliers)
  - RDC developed statements of work and followed the standard acquisition processes to award contracts for vessels and equipment.
- Public affairs
  - Public affairs and dissemination of information to the media was managed jointly by personnel attached to the Incident Command Center (ICC).
- Incident Command Structure (ICS)
  - Permission was obtained to establish an ICS operation center in a meeting room of a nearby public skating arena (Little Bear East Arena in St. Ignace, MI).
  - A major component of the demonstration planning document was consideration and inclusion of the necessary forms to comply with ICS practices.
- Environmental
  - The principal environmental issue was to obtain permission from the Michigan DEQ in order to employ limited quantities of peat moss and oranges as environmentally benign surrogates for an oil spill. The letter of permission appears in APPENDIX F.

4 INCIDENT COMMAND CENTER

An ICC was set up in the nearby Little Bear East Arena in St. Ignace. CG personnel were assigned to perform specific functions within a limited incident command structure. The ICS components for the exercise consisted of:

- Planning Section
- Operations Section
- Staging Area Manager
- Situation Unit Leader
- Resources Unit Leader
- Liaison Officer

The ICC maintained and distributed daily an updated ICS Form 204. This form is the Assignment List that is used during an incident to identify teams, their leaders and assignments. This facilitated tracking all participating personnel, their duty station, and cell phone contact information.

The ICC was the hub for cell phone and very high frequency (VHF) shore-to-vessel communications and was able to monitor real-time video imagery down-linked from the Aerostat IC EO and IR cameras when the Aerostat was aloft.

Each morning of the exercise, personnel in the ICC conducted a pre-deployment brief which covered weather and ice conditions, safety issues, and the daily operational plan. Attendance at this meeting was mandatory for all vessel captains and equipment team leaders. These meetings served to improve daily mission planning and focus and situational awareness.

5 LOGISTICS

5.1 Loadout

Loadout operations were conducted on Tuesday, 19 February 2013 in inclement weather conditions with temperatures in the high teens to low 20's, with low visibility due to blowing snow, and wind gusts up to 35 kts. Pier surfaces had not been recently plowed and were covered with at least 6" of hardened and rutted snow and ice. Figure 1 shows the weather and condition of the pier during loadout. The surface was slippery and generally provided unsafe footing. Precipitation and temperatures had potential for inducing hypothermia in ill-equipped/clothed personnel. With safety being of paramount importance, great care was taken to prevent injuries or accidents. There were no major adverse incidents, only a few slips and trips. The Salvation Army attempted to set up a warming tent on the pier but abandoned the effort when the structure became unstable due to high winds and snow loading. Subsequently, they were able to set up a warming station with warm beverages, snacks, and box lunches in a nearby warehouse. Lessons learned from the previous year's exercise resulted in the contracting of appropriate crane and forklift assets capable of safely lifting and moving the anticipated equipment loads. Figure 2 shows a second crane to facilitate handling on the barge deck. With several pieces of equipment shipped to the pier in Container Express (CONEX) (ISU 90) type containers, fewer crane lifts were required to transfer equipment from dockside to vessels. Figure 3 shows the CONEX boxes secured to the deck of the CGC Hollyhock.

5.2 Un-load

Despite blowing snow and gusty winds, the un-load operation was mostly complete by mid-day, Friday, 22 February. The rutted hard-packed snow cover on the pier added a degree of difficulty to the un-load; however, the operation was safely completed.

Figure 1. Station St. Ignace pier during loadout.

Figure 2. Crane on barge deck assisted in loadout of bucket skimmer and Aerostat IC container.

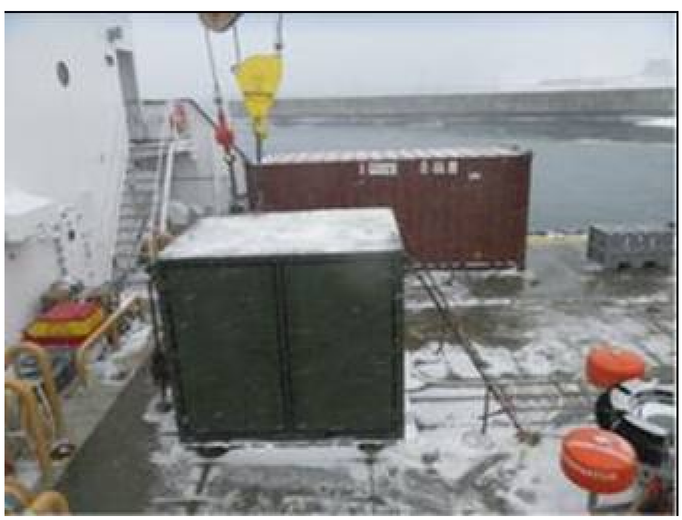

Figure 3. CONEX boxes loaded onto CGC Hollyhock deck.

6 EQUIPMENT AND OPERATIONS

6.1 DESMI Helix Skimmer

6.1.1 DESMI Helix Skimmer: Day 1

The DESMI Helix skimmer, associated hoses, and control unit were easily removed from their ISU 90 container and secured onto the deck of CGC Hollyhock. Assembly and interconnection of hydraulic lines and hoses was accomplished by the efforts of several crewmembers, NSF, and District Response Advisory Team (DRAT) representatives in less than an hour as the vessel proceeded from the Station St. Ignace pier to a mixed open water and ice-covered location just east of the Mackinac Narrows Bridge. Figure 4 shows the skimmer on deck being prepared for deployment. Having personnel and crew with prior experience with the apparatus was of significant assistance. The system remained assembled overnight in preparation for the next day.

Figure 4. DESMI Helix Skimmer on deck of CGC Hollyhock being readied for deployment.

6.1.2 DESMI Helix Skimmer: Day 2

The DESMI Helix Skimmer was successfully deployed on the second day of the exercise using the CGC Hollyhock bow-mounted boom crane. The skimmer was lowered into an open water pocket surrounded by broken plate ice and positioned by the crane into open pockets to best collect the peat moss oil simulant. See Figure 5. Concerns were raised regarding potential damage to the skimmer hydraulic control lines and hoses from contact with large blocks of floating ice. This issue was identified in the previous demonstration and has not been addressed. Recovery of the skimmer following the deployment went without any issue.

Figure 5. Skimmer deployed from CGC Hollyhock in ice-infested water.

6.2 Fire Monitor Herding

6.2.1 Fire Monitor Herding: Day 1

Fire monitor herding was not scheduled for Day 1 of the demonstration.

6.2.2 Fire Monitor Herding: Day 2

A stern-mounted fire pump and hose nozzles were installed on tugboat vessel (T/V) Erika Kobasic. The tugboat was tasked with demonstrating a high-pressure and high-volume fire hose system that could be used to direct, localize, and concentrate spilled oil, facilitating recovery. To demonstrate technique effectiveness, floating oranges and peat moss were deployed to simulate oil targets. Figure 6 shows the peat moss being herded by a stern-mounted fire monitor. Once on-scene in an area with open water and sparse solid/brash/broken ice, a large pump was lowered down the port stern side and supplied a tri-nozzle platform secured to the stern of the tugboat. Figure 7 shows all three water cannons of the fire monitor in herding operation. The Erika Kobasic attempted to direct streams of water at the simulated oil target and herd it into position for convenient recovery. APPENDIX G provides details for this tactic. The peat moss and orange oil spill simulant was herded towards the bucket skimmer mounted on the bow of the nearby barge and adjacent ice edge. Figure 8 illustrates this tactic. Using the two smaller side cannons did not seem to work as well as using the single center large water cannon for herding in open water.

Figure 6. Peat moss oil simulant (center of photo) being herded by water stream from stern-mounted fire monitor.

Figure 7. Fire monitor employing all three water streams to herd peat moss oil spill simulant.

Figure 8. Peat moss being directed towards ice edge and bucket skimmer mounted on barge.

The Erika Kobasic proceeded to try an assortment of high-stream water pressure jets and directing techniques to drive the oil simulant to the target area. It was difficult to direct the peat moss in a straight path because the wind and water current tend to drive the peat moss in a dispersed fan pattern rather than a straight line. The stern-mounted water cannon provided a challenge for the skipper to maneuver the tugboat because of the obstructed view from the bridge to the tugboat stern. Verbal communication between the skipper and fire monitor operators coordinated vessel maneuvering and fire monitor operation. The consensus was that a bow-mounted fire monitor configuration would improve efficiency of herding operation. Multiple vessels with monitors would be much better for herding oil in the open water. Use of a boom on the outboard side of the barge could help concentrate any oil that is herded. Booms may be placed along the ice edge if the edge is not well defined and deep enough.

6.3 American Fireboom MKII® Boom System

6.3.1 American Fireboom MKII Boom System: Day 1

A "practice version" of the American Fireboom MKII boom was transported to the operational area onboard the barge. Deployment of the boom followed a standard maritime practice of faking out its length for deployment from the barge deck. Figure 9 shows the boom staged for deployment on the barge deck. It is important to note here that the boom would not typically be deployed from a vessel in highly concentrated ice but is normally deployed from vessels in open water. However, this was an important aspect of the exercise highlighting tug maneuvering challenges in keeping steady course to avoid entanglement on the barge corner bollards. The tug had to continuously change headings and adjust speed to maintain a steady course. Linear sections of the boom were pulled off from the barge by the Tug Erika Kobasic into loose ice. High winds made it particularly difficult, time-consuming, and potentially hazardous deploying and retrieving the boom by means of the crane in highly concentrated ice conditions. It has been suggested that boom deployment from reels on the barge or off the tug decks might be less difficult and time-consuming. Figure 10 shows the boom being towed from the barge by one of the tugs. The two tugs, Nickelena and Erica Kobasic were tasked with towing the American Fireboom MKII boom through broken ice while using floating oranges as simulated oil targets. The boom was towed at speeds, not exceeding 3 kts, astern of the two tugs in a U-shaped configuration. APPENDIX G provides general details for this tactic.

Figure 9. American Fireboom MKII boom faked out and being deployed.

Figure 10. Tug towing American Fireboom MKII boom while being deployed from barge deck.

Figure 11 shows the boom in the U-shaped configuration with captured ice, peat moss, and oranges. Several practice efforts were made using the American Fireboom MKII boom containing broken ice along with orange and peat moss oil simulant. Slow speed maneuverability was essential for this operation; the tugs being able to effectively maneuver at 1 kt or less allowed them the fine control necessary to accomplish this. The tugs appear to have ideal characteristics for in-situ burning (ISB) boom-handling in ice-infested water conditions. They have good slow speed capability and maneuverability necessary for boom towing operations. Proceeding at slow speed limited the amount of oil that could be pushed further under the ice by excessive prop wash or could escape beneath the boom skirt. A bow thruster also adds to the vessel's maneuverability in ice-choked waters, giving the operator more control during the towing situations.

With the barge located in ice, the boom was towed back to the barge. The boom was then recovered using a large crane on the barge deck. Figure 12 shows a boom section being recovered from the water back onto the barge deck from ice-choked water using the crane. High winds and re-freezing ice made it particularly challenging. Recovery of a boom from ice-choked waters as opposed to open water using the barge-mounted crane proves difficult, time consuming, and potentially hazardous. The retrieval operation took approximately 2 hours. During retrieval using the crane on the barge, it became visible that the boom had been damaged during the day's operations. It appeared that the bulk of this damage occurred during the operation, and retrieval efforts as it was crane-lifted and dragged over and through the dense ice pack surrounding the barge. While the crane's hook was being removed from one boom section and connected to a new section, the rest of the unrecovered boom would re-freeze in the ice causing difficulties. Robust fire booms are needed if this type of tactic is used in the future. In addition, ice-breaking capability may be necessary for arriving on scene and operating in ice-choked waters. Depending on the thickness and percent of ice cover, an ice breaking-capable vessel may have to precede tugboat operations.

Figure 11. American Fireboom MKII boom being towed in U-shaped configuration by two tugs; ice can be seen captured by the boom.

Figure 12. American Fireboom MKII boom being recovered by crane from barge deck.

Figure 13 shows the boom lying on the surface of broken and refrozen plate ice. This damage and the related safety issues may be avoided in the future by launching and retrieving the boom in open water. During the retrieval process, the tugs dropped the boom towlines, still attached to the boom, into the water. As the boom was being retrieved, these lines also began to freeze into the frigid water and onto nearby ice plates, making retrieval more difficult. In the future, these towlines should be detached from the boom and immediately retrieved by the tugs at the beginning of the boom recovery process.

Figure 13. Boom lying on broken and refrozen plate ice.

6.3.2 American Fireboom MKII Boom System: Day 2

The American Fireboom MKII Boom System was not scheduled for deployment on the second day of the demonstration.

6.4 Lamor Oil Recovery Bucket (LRB)

6.4.1 LRB: Day 1

The LRB system was not scheduled for deployment on the first day of the demonstration.

6.4.2 LRB: Day 2

From its hard-mount tie-down position at the bow of the barge, the skimmer demonstrated operation by recovering peat moss oil simulant from a pool of open water surrounded by broken ice. Figure 14 shows the skimmer as it was mounted on the bow of the barge and Figure 15 provides a closer view of the skimmer head being deployed. It also demonstrated the ability to use the articulated arm to move small plates of ice out of the way to create an open water pool for collection of the peat moss oil simulant. To change collected oil viscosity, a hose from a water source could be used to supply water to a hot water generator or pump to inject either cold or hot water into the pump discharge. However, logistics did not allow demonstrating the cold-weather aspects of this process and the water source was not used. The barge-mounted skimmer participated with a fire monitor-equipped tug to demonstrate collaborative oil herding and skimmer oil collection. With the barge angled into an ice sheet, a pocket for oil collection was created between the barge hull and the ice sheet. Figure 16 shows how the skimmer boom was used to move ice out of the way for skimmer operation. Some sort of mechanical 'strainer' configuration to keep smaller bits of ice from the skimmer brush might be helpful in maintaining an ice-free pool for bucket skimmer operation. An important consideration for future research and development is what, if anything, needs to be done to prevent a long length of hose in extreme cold from freezing. Another consideration for planning purposes is that if the pusher tug is to be the source of heated water for the water injection for the skimmer discharge pump, then the tug must remain connected and cannot break away for other purposes. Ideally, for most efficient operation in cold weather, a hot water generator and storage tank for water should be collocated with the skimmer in case it is needed no matter which platform the skimmer is on.

Figure 14. LRB skimmer in process of being deployed from bow of barge.

Figure 15. Close-up view of LRB skimmer.

Figure 16. Skimmer boom arm demonstrating ability to push ice out of way.

6.5 Rutter Sigma 6 Oil Spill Detection System

6.5.1 Rutter Sigma 6 Oil Spill Detection System: Day 1

The Rutter system was installed on the bridge and integrated into the navigation radar system of the CGC Hollyhock during the prior day's loadout operation. This radar's display screen was installed nearby the vessel's "slave" radar display in an area immediately aft of, and adjacent to, the bridge. For purposes of comparison, the parameters of the vessel's navigation radar screen were set by one of the vessel's bridge crew to provide a display image quality as would typically be employed for navigation operation. On transit out to the area of operation, the manufacturer's representative briefed observers on the capabilities and operation of the system. Lake surface features (e.g., open water, plate ice, rubble ice, and wind rows) were clearly identifiable on the Rutter display while not appearing well defined on the vessel's navigation radar display. Figure 17 illustrates a side-by-side comparison of navigation radar and Rutter radar displays for the same scene. The displays of the Rutter system and the vessel's navigation radar were frequently compared, both visually and qualitatively. Features identified on both radar screens were visually confirmed by going out on deck and sighting along the azimuth to particular features as indicated on the radar display. This provided a qualitative comparison of the two displays. The ice and lake surface features were clearly identifiable on the Rutter radar display out to a range of approximately 3 nautical miles (nm). When displayed range was expanded beyond 3 nm, the surface conditions resolution appeared somewhat diminished. Because there was no actual oil spills to be observed, there was no opportunity to evaluate the system's ability to discriminate and display a signature indicating the presence of oil. On several occasions, the vessel's navigation radar screen settings were "tweaked" to determine if the image of the lake surface features could be improved. Even under the best navigation radar setting conditions, the imagery displayed on the Rutter display provided significantly superior surface texture information.

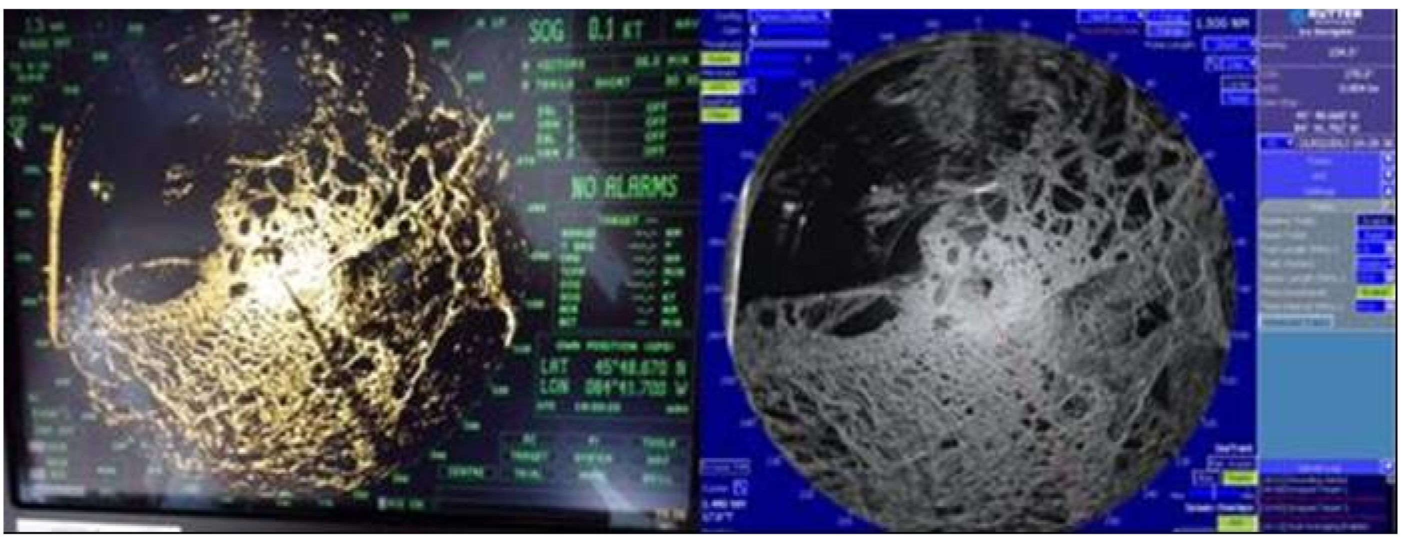

Figure 17. Side-by-side comparison of navigation radar (left) with Rutter radar (right) displays for same scene; bright vertical line near left edge of both displays is reflection from Mackinac Narrows Bridge; both displays are set to show maximum range of 1.5 nm.

6.5.2 Rutter Sigma 6 Oil Spill Detection System: Day 2

Operation, observation, and visual qualitative comparison of the Rutter radar image with the vessel's navigation radar continued much as on Day 1. Enroute to the operational area, the captain of the CGC Hollyhock requested that the Rutter radar operator locate a sizeable sheet of solid plate ice, and later a large area of open water. In both cases, the requested surface conditions were successfully identified and the captain provided with a Global Positioning System (GPS) position of the feature. Upon arrival at the stated GPS coordinates, the lake surface appeared as earlier correctly identified on the Rutter radar. Again, the Rutter radar display provided greater lake surface detail than was obtainable with any setting adjustment of the vessel's navigation radar. Figure 18 provides a side-by-side photographic comparison of the Rutter radar screen image with that of the navigation radar. The Rutter system, along with being able to store raw radar data, is capable of providing high-resolution screen captures for archiving and later analysis. The navigation radar did not have similar capabilities available, necessitating photographing the radar screen to record images.

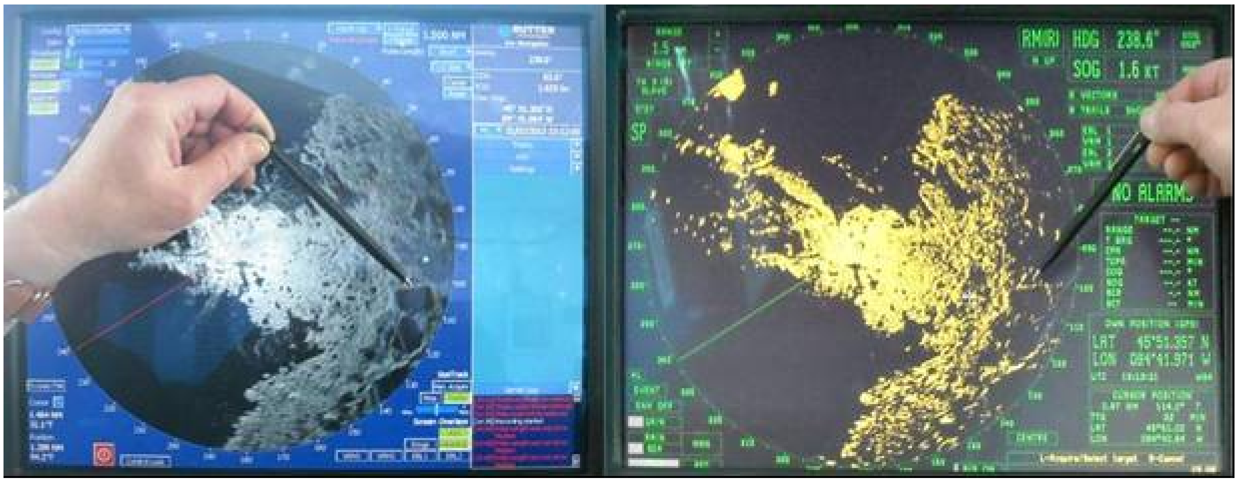

Figure 18. Hand with pencil points to same plate ice feature as displayed by each system; Rutter radar display is on left and navigation radar display on right; maximum radar range displayed is 1.5 nm.

The lake surface feature detail on the Rutter system provided the best resolution on maximum range settings up to 3 nm. The pencil is pointing to the same plate ice feature in both images. Beyond that range setting, the Rutter display surface detail began to lose resolution. Nevertheless, even at ranges up to 5 nm (the maximum tested), the Rutter system showed superior surface detail to the navigation display. Figure 19 shows a screen capture of the Rutter radar display taken nearby the Mackinac Narrows with various ice features annotated. Plate ice features appear as mottled gray/white shaded shapes, open water appears as a solid black shapes, and rubble and windrow features appear in predominantly white textures. Open water, plate ice, refrozen rubble ice, and refrozen vessel tracks are clearly visible. As on the prior day, features identified on both radar screens were visually confirmed by going out on deck and sighting along the azimuth to particular features as indicated on the radar display. This provided a qualitative comparison of the two displays. Beyond that level of screen-to-scene comparison, a more rigorous, detailed, quantitative experiment would be necessary. Figure 20 shows a Rutter radar screen capture associating photos of ice conditions to specific features on the radar display. Figure 21 shows a Rutter radar display for the same area but to a maximum radar range of 4 nm. The bright vertical line on the left side of the image is a reflection from the Mackinac Narrows Bridge.

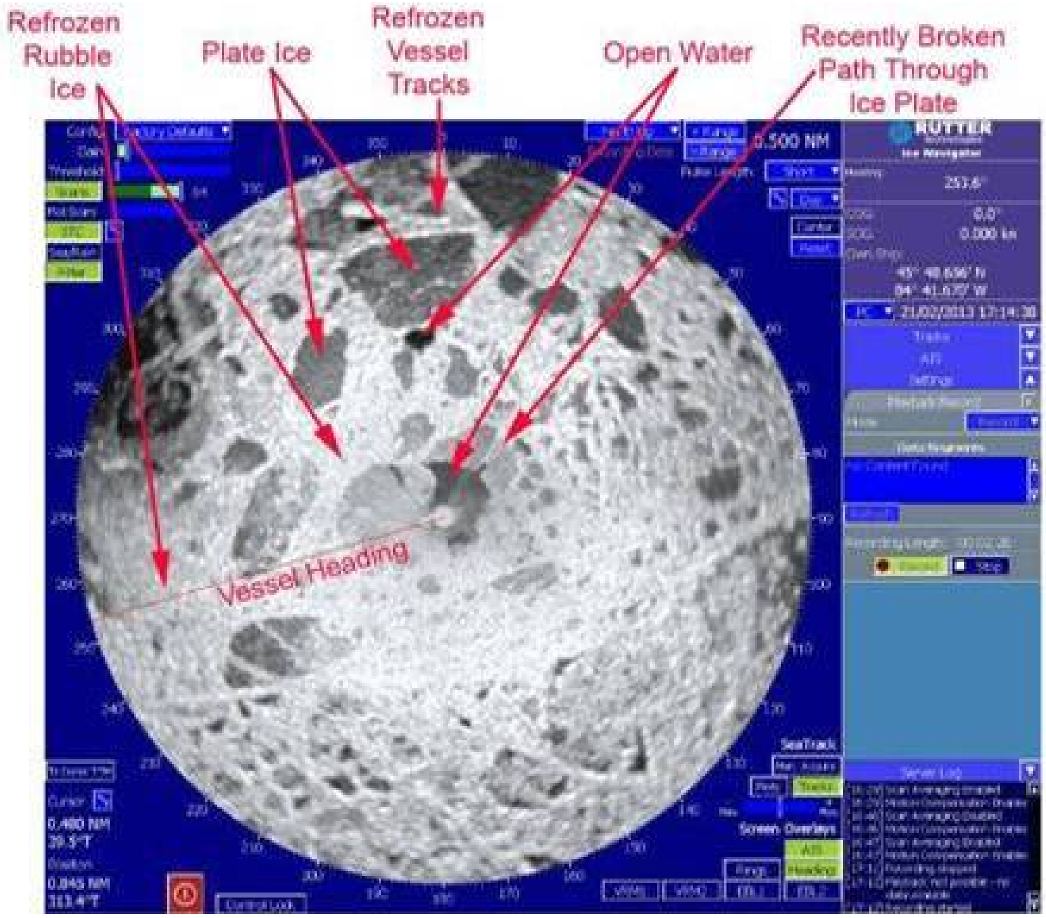

Figure 19. Several ice surface features during demonstration are indicated and identified; maximum radar range of displayed image is 0.5 nm.

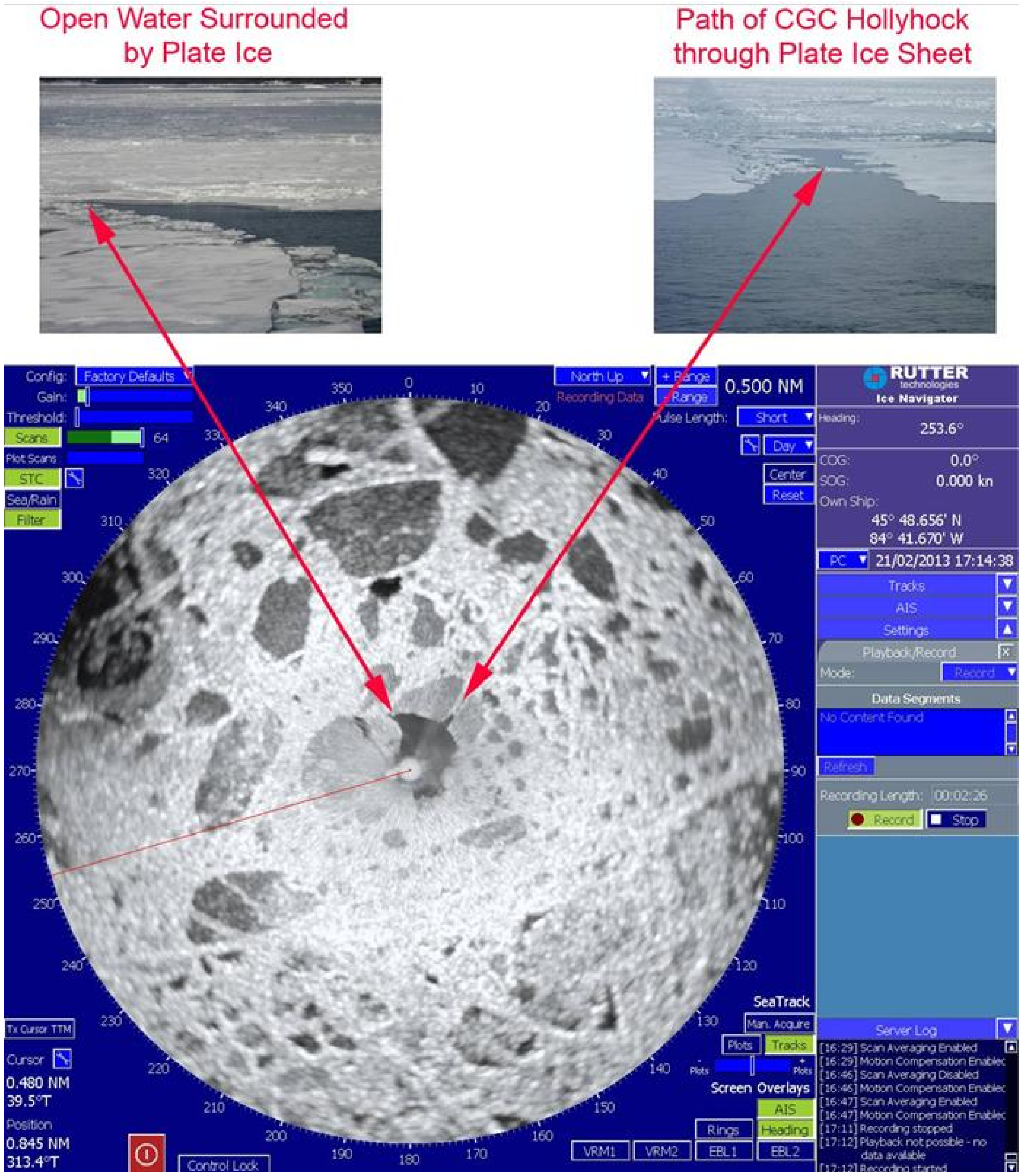

Figure 20. Photos of lake surface features are compared to their appearance on Rutter radar display; maximum radar range of displayed image is 0.5 nm.

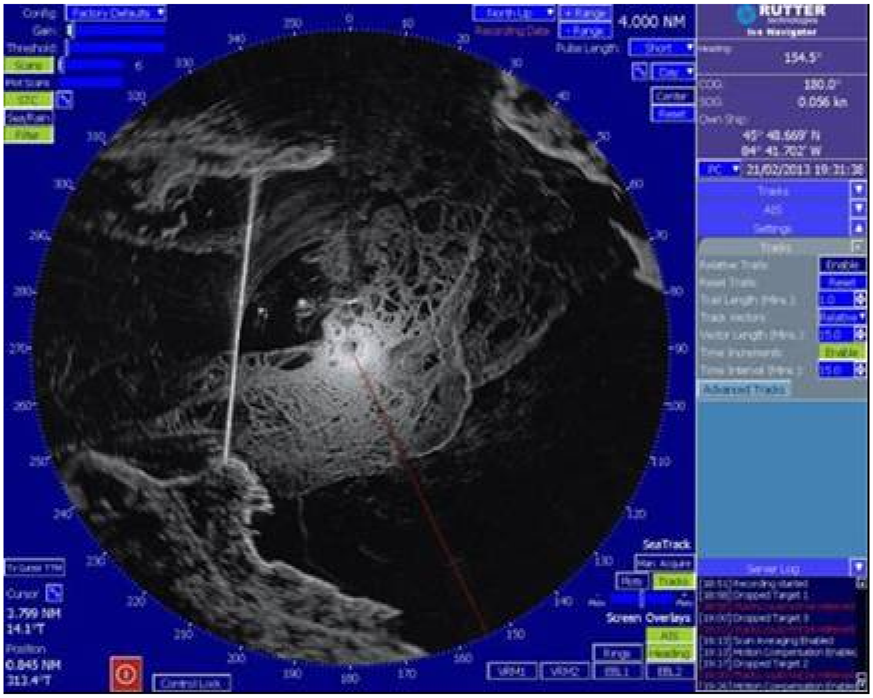

Figure 21. Rutter radar display image of same scene as in earlier figures but to a maximum radar range of 4 nm; bright vertical line to left of center of display is reflection from Mackinac Narrows Bridge.

Subsequent to the field exercise, a sample of the raw radar data files collected was post-processed using the Rutter oil detection algorithm. This post-processing technique is identical to that which would be performed in real-time if the oil detection capability was employed on an equipped vessel while underway. The algorithm identified a potential oil slick (as is defined by the polygon in Figure 22). In this case, the identified region is actually a false alarm. The cause of this false alarm is related to the lack of fetch not allowing wave action to build and provide backscatter contrast between an oil-covered region as compared to that of an oil-free region. Additional work is needed in order to use this in ice conditions. Other sensors such as IR cameras may be able to reduce some of the false alarms. Oil that sets up along an ice edge may be identifiable if the wind is pushing it and it extends out enough from the ice to ensure the leading edge is outside the shadow of any wind obstructions.

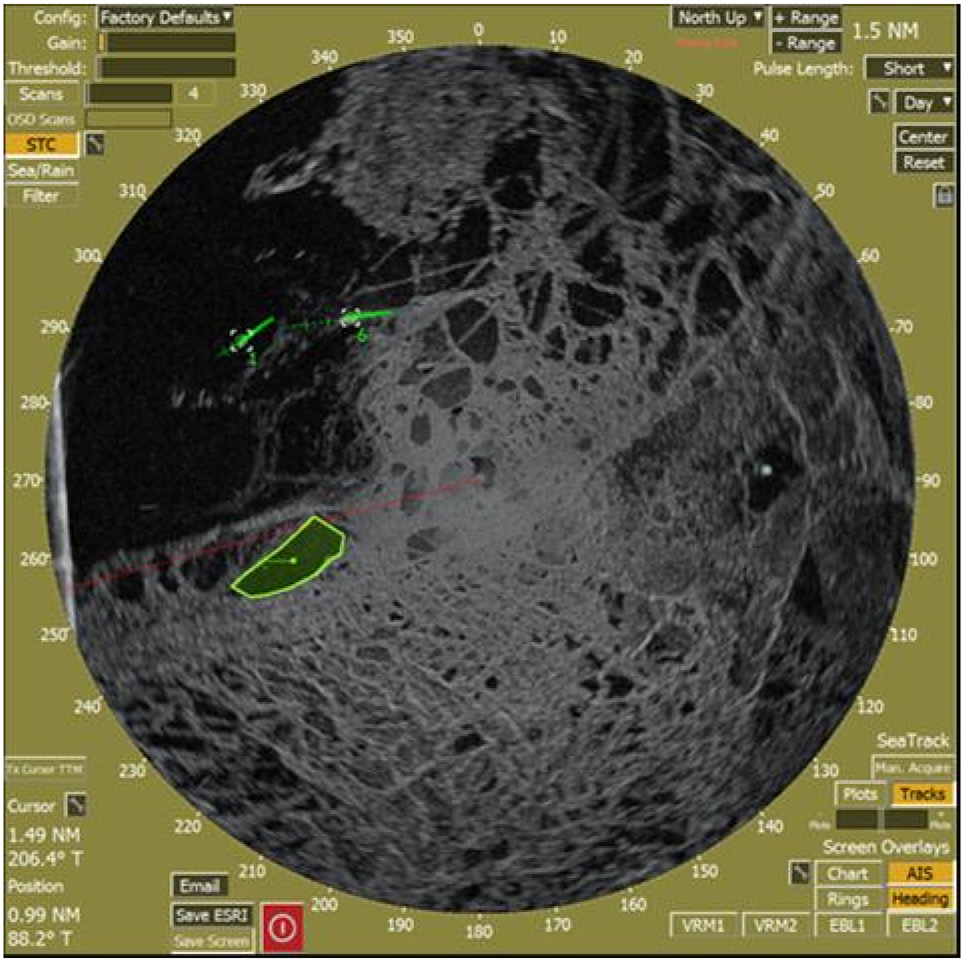

Figure 22. Rutter radar display screen capture of possible oil slick (enclosed by polygon) as indicated by Rutter oil detection algorithm; two artifacts on screen marked as "1" and "6" are tracks of two nearby vessels.

6.6 Aerostat IC

6.6.1 Aerostat IC: Day 1

Attempts were made to launch the Aerostat IC balloon with a payload of a remotely controlled EO and IR real-time video camera from the barge deck. Due to the cold temperatures limiting the expansion of the helium gas, it took more than the expected quantity to inflate the balloon to full volume. Once fully inflated, the balloon was released, on tether, from its mount on the barge deck, and there was significant difficulty getting it aloft. While the balloon has an operational history of successful launches in moderate to high wind conditions, operators were not able to effectively deploy the balloon from the barge deck in gusting winds. After several unsuccessful attempts, the launch was scrubbed for the day. It was surmised that wind turbulence and eddies generated by interfering structures, including a nearby crew shelter and a large crane mounted on the barge deck, inhibited the balloon from attaining a vertical launch. Having an unbalanced payload due to the unadjusted support lines may have also contributed to some of this imbalance. Figure 23 shows the balloon affected by turbulence and wind eddies.

Figure 23. Aerostat IC balloon hindered by wind turbulence and eddies upon initial launch.

6.6.2 Aerostat IC: Day 2

Equipment on the barge was rearranged to provide a more unobstructed launch area for the Aerostat IC balloon which had remained inflated overnight and closely secured to its launching container. Figure 24 shows the fully inflated balloon secured to its storage container on the barge deck. With winds greatly diminished, the tethered liftoff of the balloon proceeded without any difficulty. Figure 25 shows the Aerostat IC balloon and payload as it was being launched. Figure 26 is a close-up view of the balloon camera and transceiver payload. During different times of the day, balloon altitude was varied from 500' to 700' above the barge. Figure 27 shows the balloon at operational altitude. Shortly after attaining operational altitude, the balloon payload of remote-controlled EO and IR video cameras commenced transmitting real-time video images to monitors on the CGC Hollyhock, one of the tugs, and the ICC. The cameras were remotely panned, tilted, and zoomed to display wide view and detailed close-up real-time imagery of the area of operation. As an aside exercise, several CG surface swimmers in dry suits entered onto the lake ice and into the water from the CGC Hollyhock. Both the EO and IR imagery clearly showed the swimmers in the water. With full zoom, the individual swimmers were clearly identifiable at a slant range of over 2 miles from the video cameras. Figure 28 is a photograph of an EO image as displayed on the Aerostat handheld monitor showing four CG surface swimmers walking on the sheet ice. The distance between the Aerostat and the surface swimmers was approximately 2 miles. At the end of the day, the balloon and its video camera payload were safely and successfully recovered. The visual imagery was reported as extremely useful in terms of situational awareness among all vessels underway and the Command Center. The tug captain pushing the barge mentioned that it allowed him to see the bow of the barge, which was otherwise obstructed by the crane, and maneuver much more effectively. Figure 29 shows a remote handheld monitor displaying a downward-looking image from the Aerostat IC EO video camera. Figure 30 is a photograph of the monitor screen showing an oblique view of a tug with fire monitors herding peat moss oil simulant.

Figure 24. Aerostat IC balloon secured to its storage container on barge deck.

Figure 25. Aerostat IC balloon and payload in process of being launched.

Figure 26. Closeup of Aerostat IC payload showing EO and IR cameras and radio data link hardware.

Figure 27. Aerostat IC balloon at operational altitude.

Figure 28. Photograph taken from handheld display of an Aerostat EO image of four CG surface swimmers from CGC Hollyhock walking on lake ice (indicated by arrows); image taken from approximately 2 miles distance.

Figure 29. Downward look at barge and tug from Aerostat IC EO sensor shown on handheld display.

Figure 30. Oblique scene view from Aerostat IC EO camera as viewed on handheld display of fire-monitor-equipped tug employing herding tactics on peat moss oil simulant.

6.7 Deep Ocean HD2 ROV

6.7.1 Deep Ocean HD2 ROV: Day 1

The ROV was scheduled for deployment from the deck of the CGC Hollyhock carrying a payload of the EIC Laboratories, Inc. underwater fluorescence polarization sensor. Two sonars from RESON were also provided. One sonar could be mounted in an upward-looking configuration and the other in a forward-looking arrangement. However, with the sinking of the AUV, the ROV was brought into service to locate and recover the AUV. The EIC Laboratories underwater fluorescence polarization sensor was removed from the ROV for this operation and the forward-looking configuration was mounted on the ROV. Figure 31 shows the ROV being launched from the CGC Hollyhock during AUV recovery operations.

Searching was conducted for about 1 hour until it was apparent that the bathymetry was causing many false targets. The ROV has a grappling/recovery attachment which was not immediately available on scene. Instead, crewmembers of the CGC Hollyhock jury-rigged a steel rod in the shape of a "shepherd's crook" which was attached to the frame of the ROV with stainless steel hose clamps. Figure 32 is a close-up of the ROV with the attached jury-rigged recovery hook. The sonar was removed and searching was continued visually using the camera system by driving the ROV down a transponder line that was hanging from the vessel. This transponder was providing a range to the AUV but could not calculate a bearing. After another hour of intense searching of the lake bottom in a collaborative effort by the ROV operator, AUV personnel, and CG crew, the AUV was located. It was recovered just prior to 1930 Eastern Standard Time (EST) in darkness. Figure 33 shows the ROV with the recovered AUV as both returned to the surface. This unplanned exercise illustrated the wide utility and precision control of the ROV and flexibility and ingenuity of CG crew and equipment operators in solving an unexpected technical challenge.

Figure 31. ROV being launched by crane from the deck of CGC Hollyhock.

Figure 32. Close-up of ROV showing jury-rigged "shepherd's crook" recovery hook (lower left of image).

Figure 33. ROV with retrieved AUV return to the surface.

6.7.2 Deep Ocean HD2 ROV: Day 2

The ROV was deployed by crane from the deck of CGC Hollyhock and remained in the water, on standby, moored adjacent to the vessel hull while the AUV was subsequently deployed by crane and operated. Unfortunately, the ROV instrument payload consisting of the EIC Laboratories fluorescence sensor suffered damage subsequent to being removed from the ROV to facilitate the Day 1 recovery of the malfunctioning AUV. This sensor was therefore not deployed and the newly developed scanning capability was only demonstrated on deck. The upward-looking sonar was mounted and the ROV was driven under the ice. Output from the sonar could show the bottom of the ice, but the instability of the relatively small ROV resulted in data that could not be correlated. Either the ROV would need to incorporate some type of stabilization which usually requires a larger ROV, or compensation software would be needed in order to collect useful data. This size of ROV could still be used for visual searching but it is still not clear how the locations of the oil can be marked when found.

6.8 AUV

6.8.1 AUV Loadout Day

On the afternoon of loadout day, after the CONEX container was lifted onto the deck of the CGC Hollyhock, the AUV operators unpacked and prepared the unit for operation. Several hours were needed to adjust the buoyancy of the AUV for proper operation in freshwater. It had earlier been used in the more buoyant seawater environment. The process needed several trial-and-error evolutions requiring addition and adjustment of buoyant material followed by a crane lift into the lake water. Figure 34 shows the unpacking and preparation of the AUV while the CGC Hollyhock was docked at Station St. Ignace. One of the other operational issues that needed to be addressed is that the AUV needed to be in a warm environment (over about 55 °F) in order to charge the batteries. Heaters were brought in to heat the container but the size of the container, the fact that the door could not be sealed during overnight charging, and weather caused the temperature to barely make the minimum.

Figure 34. Unpacking and preparing the AUV for operation.

6.8.2 AUV: Day 1

The AUV was launched (Figure 35) using the deck crane of the CGC Hollyhock into an area of open water. While remaining connected to the crane, buoyancy, communications, and control functions of the AUV were tested. Once function was confirmed, the AUV was disconnected from the crane to commence autonomous operation. Shortly after submerging, the ability to control the AUV ceased. Without control of propulsion, the AUV sank and settled to the bottom of the lake in approximately 120' of water. Acoustic communications from the AUV to the surface continued but commands could not be sent down. After several attempts to regain control, it was determined that the AUV could not return to the surface under its own power. The buoyancy of the unit was also too low in the fresh water for the system to float to the surface, one of the emergency recovery methods. The ROV with a jury-rigged "shepherd's crook" recovery hook was pressed into service to locate and recover the AUV. The AUV was located on the lake bottom by means of acoustic triangulation involving transducers on the AUV, ROV, and a third acoustic transducer placed over the side of the CGC Hollyhock. The location and successful recovery of the AUV was an intensive and skillful collaborative effort between the AUV operator, the ROV operator, and CG crewmembers. After retrieval, the AUV operators determined that the malfunction was most likely the result of ice formation on one of the vessel's fathometers combined with a software glitch.

Figure 35. AUV being launched by crane from deck of CGC Hollyhock.

6.8.3 AUV: Day 2

The technical issues that caused the malfunction of the AUV during the previous day had been rectified overnight by the AUV operation team. The AUV was launched (Figure 36) and performed an abbreviated underwater mission demonstrating that it could operate independently under open water and beneath lake ice cover, going out about 100 meters under the ice..

The information recorded during this deployment is representative of the options that could be considered. The data that was recorded included a dead-reckoning position of the vehicle, water depth, depth of the vehicle, water temperature, water velocity (with respect to vehicle and computed with respect to the ground), ice draft and radiance as measured by an upward-looking hyperspectral sensor. A sample set of data is shown in Figures 37-39. Figure 37 provides an x-y position plot of the vehicle's motions. The colored lines indicate the depth as seen in the colored legend at the bottom of the figure. The top of Figure 38 displays the depth of the vehicle and the bathymetry of the bottom as the vehicle passed over. The Acoustic Doppler Current Profiler (ADCP) measures the relative motion of water past the vehicle, then calculating the speed and heading of the vehicle, determines the local current conditions. All three dimensions of the relative and actual currents are plotted in the bottom of Figure 38. The ADCP provides input for the dead-reckoning tracking since GPS cannot be received under ice. The ice draft measured by an upward looking fathometer, can be seen in the top chart in Figure 39. Note that the vehicle was deployed under the buoy tender so the draft calculation of about 6 meters is the hull being detected toward the right side of the chart. The bottom chart in Figure 39 shows the radiance; with the higher values in pink and blue in open water before diving at the right side of the figure. and greenish colors for lower light levels under the ice. It is expected that oil would reduce this value even further. The combination of the ice draft and radiance is a potential combination for oil detection. Other sensors can be used in the future.

Figure 36. AUV operating on surface immediately following launch.

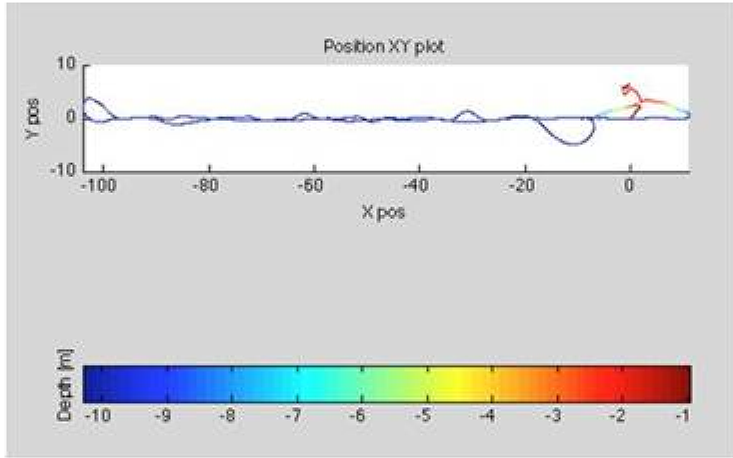

Figure 37. Position plot of AUV.

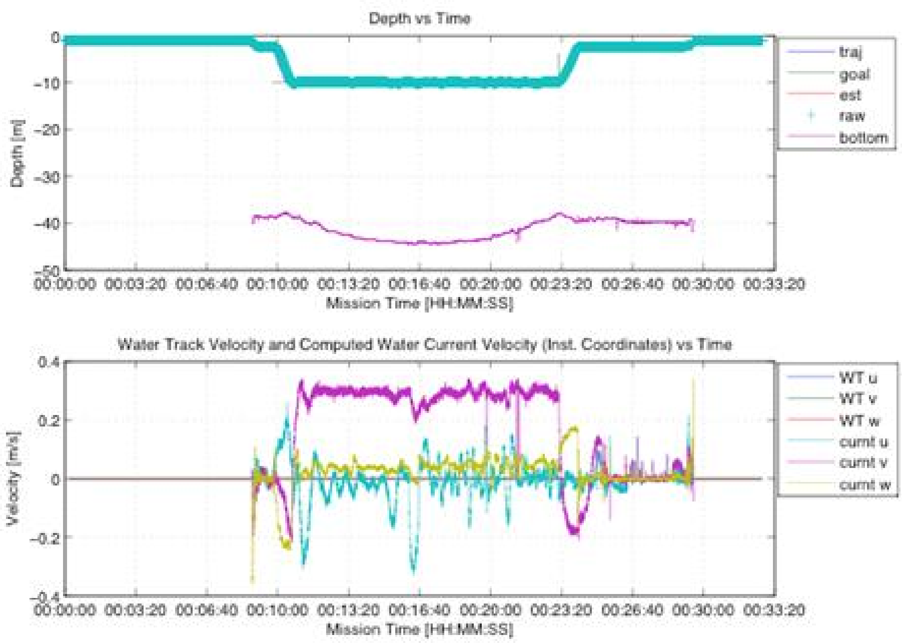

Figure 38. Data collected from depth sensor, fathometer and ADCP.

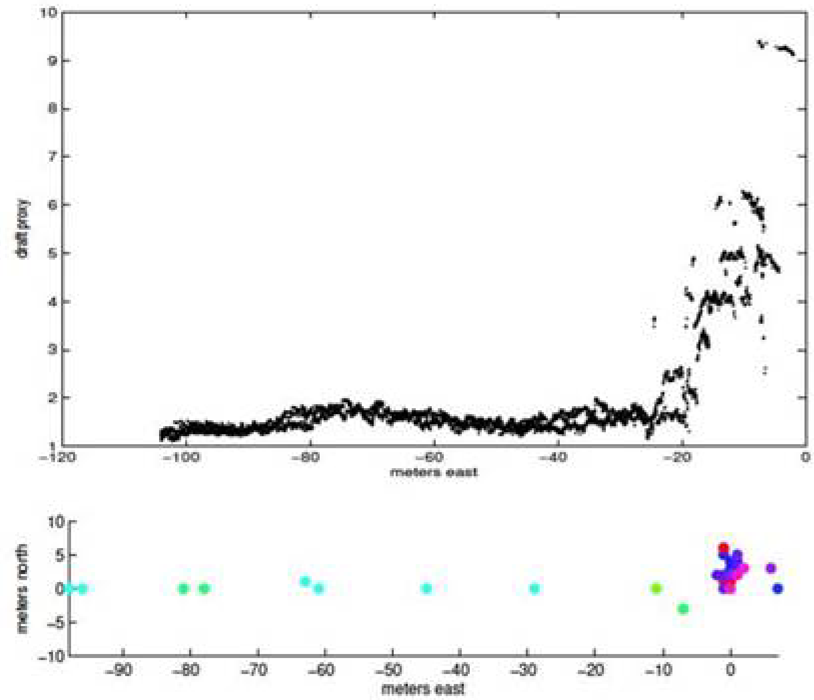

Figure 39. Ice draft (top graph) and Hyperspectral Radiance (bottom graph) from AUV.

7 LESSONS LEARNED AND OBSERVATIONS

There were multiple comments from all of the participants about what was seen and what other issues still need to be resolved. These were recorded by RDC and SAIC personnel during the demonstration, as well as during quick hot-wash meetings held at the end of each day and at a summary meeting the last day. Some of these cover more than one area so may appear in more than one of the categories below. One of the main issues identified in this and the previous evolutions is that demonstrations may vary greatly when compared to an actual spill response. In this case, multiple systems will probably not be loaded onto one platform or, as a minimum, will not be assigned multiple simultaneous tasks. Decisions about recovery of damaged equipment might also be different if the platform's mission is considered critical and the recovery mission is not a priority.

7.1 Planning

- Confirm scheduling of delivery and arrival of equipment and assets.
- Ensure flexibility of service contracts to allow for impacts of changing weather, ice conditions, equipment availability, and equipment failures.
- Ensure vessel captains are involved in operational meetings.

7.2 ICS

- ICS facilitated safety and coordination for entire demonstration.
- ICP located in good location.
- During a demonstration, more RDC presence in ICS is preferred and better communication needed.

- Lack of public affairs personnel due to budget stretched personnel in ICS.
- Local Sector had time for ICS training.

7.3 Logistics

- Loadout
  - Awareness and observance of safety in high wind, blowing snow, low-visibility, and cold weather conditions prevented mishaps and injuries.
  - Warming shelter, hot beverage, and food provided by Salvation Army aided in prevention of adverse exposure effects to participants.
  - Warming shelters should be of sufficiently robust structure to withstand high winds and snow loading.
  - Containerized (e.g., CONEX or ISU 90) ‘ready-to-go’ equipment facilitated rapid loadout, fewer crane ‘picks’, and eliminated equipment set-up in harsh environments.
  - Operation in cold, low-visibility, and high-wind environments are hazardous and require special care and awareness.
  - Snow and ice should be completely removed from loadout area for safety and ease of equipment and personnel mobility and operations.
  - Be aware of local assets that can be brought into play if needed (e.g., Salvation Army, etc.)
- End-of-Mission
  - All considerations made for loadout apply to end-of-mission.
  - All systems should be purged of water prior to storage to prevent freeze-up.
  - Provisions are needed for hazardous material (HAZMAT) decontamination, disposal, and clean-up of recovery equipment, and development of techniques specific to cold weather operations.
  - Holding a ‘hot wash’ on final day of demonstration permits discussion and recording of issues and lessons learned while still fresh in minds of participants.

7.4 Equipment

- Practice Fire Boom
  - Deploy and recover boom in open water for safety, ease, and to limit damage.
  - Freezing environment caused difficulty in boom handling.
  - Tow line (400’) must be removed first before recovering boom or else it may freeze into lake ice sheet.
  - Reduce boom damage by limiting exposure and operation in high density/high concentration ice cover.
  - Deployment by means of pulling boom laid out on deck worked well.
  - Recovery by crane was difficult and less safe while located in frozen ice and is likely to cause damage.
  - Select a boom design that is especially robust for operations in ice-infested waters.
  - Strong winds make boom recovery by crane very difficult and hazardous.
- Fire Monitor
  - Power pack provided was not intended for arctic environment use; ensure power pack is capable of easy starting and operation in extreme low temperatures.
  - Ensure onboard heating resources are available to defrost frozen pumps and fittings.
  - Pre-heating of fire monitor pump and other components (as well as tools) is helpful in set-up.

- Helix Skimmer
  - CONEX (ISU 90) box shipping container facilitated simple loadout and deployment.
  - There is potential of damage to skimmer hydraulic lines and intake hose in water from collisions with large broken ice plates.
  - To prevent damage to hoses, consider sleeve or festoon to hoist and support them above ice and waterline.
  - After being drained, residual water in lay-flat hoses may freeze hose walls together and render them unusable.
  - A crane is the optimum method of positioning skimmer in a water 'pocket' among rubble ice and directing skimmer towards concentrations of oil.
- Bucket Skimmer
  - Consider multiple 'hard point' mount locations on barge to facilitate easy and safe relocation of bucket skimmer on deck to allow reconfiguration with changing mission/tactic requirements.
  - Articulated hydraulic arm of skimmer was useful in pushing plates of ice to create open water pocket for efficient skimming.
  - Consider provision of lake/seawater intake and on-deck container for heated water source for skimmer injection operation.
  - Consider recovered oil stowage capacity needs and methods.
- Aerostat IC
  - A dark-colored Aerostat IC balloon would improve visibility when airborne and potentially increase lift due to sun's warming effect.
  - There is significant value for situational-awareness, scene and asset management, and ICS by having Aerostat IC IR and EO detailed real-time video of operation scene transmitted to vessels and ICC.
  - Wind direction, velocity, and especially turbulence/eddy effects caused by nearby structures must be considered when launching Aerostat IC balloon.
  - Situating Aerostat IC away from other equipment/structures on barge facilitates balloon launch by minimizing exposure to complex wind patterns generated by other on-deck equipment and structures.
  - Ensure a supply of significantly greater volume of helium is available to sufficiently fill balloon when operating in cold temperatures.
  - A bearing indicator should be included in transmitted Aerostat IC image to facilitate communications when describing targets to other vessels.
  - IR capability is extremely useful in man overboard rescue and operation in darkness.
  - Consider developing maximum gusting wind parameters for colder weather operations.
- AUV
  - Equipment should be pre-configured, pre-buoyancy compensated, and shipped as assembled as possible to facilitate rapid set-up and deployment.
  - Vehicle did demonstrate potential for autonomous under-ice operation and data collection.
  - Decontamination techniques have to be determined for specialized equipment.
  - Sensors, propulsion, and control surfaces should be de-iced prior to being deployed.
  - A 'ruggedized' version of the AUV must be developed before it can be considered as an operational tool.
  - Further research is needed on selection of the appropriate sensors to use and how the data is to be used by decision-makers.

- ROV
  - The ROV demonstrated the tactical value of adaptability and flexibility by performing unexpected equipment recovery tasks.
  - Ingenious jury-rigging of ROV facilitated successful recovery task.
  - System operated well with 300' tether.
  - Operation with manufacturer-specified 2200' to 5000' tether should be demonstrated to evaluate full utility of system.
  - Moving components (e.g., camera pan/tilt/focus mechanism) should be de-iced prior to deployment.
  - Consider protective shields or 'armoring' for sensors to prevent damage from ice or handling.
- Rutter Ice Radar
  - Ice radar clearly identified open water vs. ice cover up to a range of 3 nm.
  - Longer range (>4 nm) capability of radar to provide clear identification of ice conditions would be helpful.
  - Ice radar capable of displaying and identifying different ice types (i.e., plate, rubble, wind row, etc.).
  - Rutter system provided significantly higher detail information of lake ice surface conditions than standard navigation radar for ice navigation and ice type identification.
- General
  - Efforts and a safe storage space should be made to protect/store delicate instrumentation prior to deployment.
  - Cell phones were not reliable when operating from an open deck while underway due to cold effects on batteries and freezing of electronics. They are also difficult to handle and make calls without removing gloves. They were also more complicated than simple vessel-to-vessel VHF communications.
  - Hydraulic fluid may require heating system to operate properly in sub-freezing temperatures.
  - Icebreaker may be necessary to 'break out' and assist other vessels to make way through ice.
  - More personnel may be required to manage equipment in harsh conditions but may result in increased safety and supervision complexities.
  - Frequent crew rotations are necessary in cold weather.
  - Color-coded vests are helpful to clearly identify key personnel by function. This is especially useful in low-visibility situations and when personnel are all wearing identical extreme weather gear.
  - Environmentally sound equipment de-icing methods are necessary.
  - Ensure that contracted vessels and their crews be fully briefed and equipped for arctic-like operations.
  - Contracted vessel and equipment operators should be fully aware (and practice) appropriate decontamination procedures.
  - Investigate a bio-degradable solution and/or steam delivery system for de-icing equipment and sensors.
  - Explore special considerations and procedures for rescue and medical aide in 'man overboard' situations in ice-infested water as ice may not permit typical response of deployment of a small boat
  - Holding end-of-day hotwash (and recording findings) on each vessel while returning to pier was helpful in capturing daily lessons learned while they were still fresh in the minds of participants.

7.5 Tactics

- In general, use of limited quantities of oranges and peat moss, environmentally benign oil spill simulants, while not a perfect substitute, were useful in visually demonstrating effects/results of various oil recovery techniques and tactics demonstration.
- Mission flexibility and application of creative solutions is necessary for performing field operations.
- If possible, take advantage of wind direction to aid in herding
- Herding towards an ice edge facilitates oil collection.
- Consider a tactic of collaborative use of multiple tugs with fire monitors to efficiently herd oil.
- The two smaller fire monitor side cannons did not appear to work as well as the single center large water cannon for open water.
- Arching spray from fire monitors appeared to be more effective for herding than a strong, directed steady stream.
- Aerostat IC real-time imaging on tug bridge enhanced maneuverability and facilitated herding tactics.

7.6 Vessel Specifics

- CGC Hollyhock
  - Equipment shipped/deployed from CONEX (ISU 90) container facilitated crane loading from pier onto vessel.
  - If provision is made for heating, CONEX (ISU 90) containers, once secured on deck, can provide sheltered work space for equipment maintenance and operation.
- Tugs
  - Tug is required for barge tending/maneuvering operations.
  - Confirm that contracted vessels are capable of operating in ice conditions expected to be encountered.
  - An icebreaker may be required to ‘break out’ tugs from their frozen-in moorings and open channels through ice for tug transit to operational area.
  - Tugs were useful for towing because their maneuverability and their ability to work at slow speeds, unlike offshore support vessels that need to clutch in and out to maintain speeds needed for booms.
- Barge
  - Safety railing on barges are needed.
  - Heated shelter on barge is necessary for preventing exposure injuries to personnel.
  - Consider several deck mounting positions for bucket skimmer to allow different barge/ice orientations.
  - An icebreaker may be required to ‘break out’ barges from frozen-in moorings and open channels through ice for barge transit to operational area.
  - Maneuvering barge bow or stern into edge of ice sheet creates an ice/barge ‘pocket’ for herding and skimmer recovery of herded oil.
  - Depending on winds and currents, barge will require full-time tug tending. It is not recommended to leave barge floating free from a tugboat due to safety concerns.

7.7 General Observations (Not Elsewhere Addressed)

- Collaboration and shared experience among CG, CG RDC, contractors, and equipment vendors provided valuable lessons learned, procedural and tactical technique adaptations and improvements, and potential equipment modifications to meet specific challenges of operation in extreme cold environment and ice-infested waters.
- Prior training of equipment-handling personnel and vessel operators is critical to safe and efficient operation.
- Different recovery systems and tactics necessary for different ice and weather conditions should be available.
- Engaging contract vessel captains and crews in daily briefing is necessary for clear communications of daily operational plan and situational awareness.
- Flexibility and adaptability are key to successful operations in cold weather and variable lake ice conditions.
- Emphasis on safety awareness and practice contributed to a successful exercise.

8 RECOMMENDATIONS

- Further research/development/design of temporary storage and transportation concepts for recovered oil is necessary.
- Further consideration and practice of decontamination techniques for personnel and equipment in cold weather operations is necessary.
- Explore special considerations and procedures for rescue and medical aid in man-overboard situations in ice-infested waters.
- Investigate a bio-degradable solution and/or steam for de-icing equipment and sensors.
- Locally develop and maintain a list of vetted boats for hire based on minimum key performance parameters in extreme conditions that may be encountered. Some of these parameters may include quantifying vessel maximum safe sea state capability and maximum ice thickness breaking capability.
- Consider evaluation of a water-cooled fire boom in a future demonstration in ice.

9 SUMMARY

The objectives of this effort were successfully achieved through the demonstration of multiple pieces of equipment, procedures, and tactics for the recovery of oil in ice-infested waters. The equipment was safely deployed, the appropriate equipment and personnel to perform a response were identified, operating procedures have been developed (Appendix G) and training was done. The ICS was successfully deployed to increase safety and coordination. Recommendations for the next steps were provided.

The actual implementation of various tactics requires some responder experience to ensure tactics can be performed safely. The knowledge base has been further augmented for CG and commercial responders in the Great Lakes that increases the spill response capability in this region; and also provides input for CG D17 when considering options in their own area. Overall, the competence of the vessel crews and responders really made this demonstration successful and will serve as an initial benchmark for spill responders in the Great Lakes and as a reference for Arctic responders.

10 REFERENCES

1. "Final Great Lakes Exercise 1 Report," RDC report, Contract HSCG32-10-D-R00021/Task Order HSCG32-11-J-300015, July 2011.
2. "Oil-in-Ice Response Demonstration Final Report," RDC report, Contract HSCG32-10-D-R00021/Task Order HSCG32-11-J-300021, May 2012.
3. Alaska Clean Seas Technical Manual, http://www.alaskacleanseas.org/tech-manual/.
4. STAR Manual – State of Alaska, http://www.dec.state.ak.us/spar/perp/star/docs.htm.

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APPENDIX A. LOCAL AREA MAPS AND AERIAL IMAGES

A.1 Overall Operating Area

The demonstrations are conducted at St. Ignace, MI. Figure A-2 below depicts the geography of the general operating areas.

A.2 Eastern Upper Peninsula

Figure A-1 depicts the eastern portion of Michigan's Upper Peninsula including Sault Ste. Marie and St. Ignace.

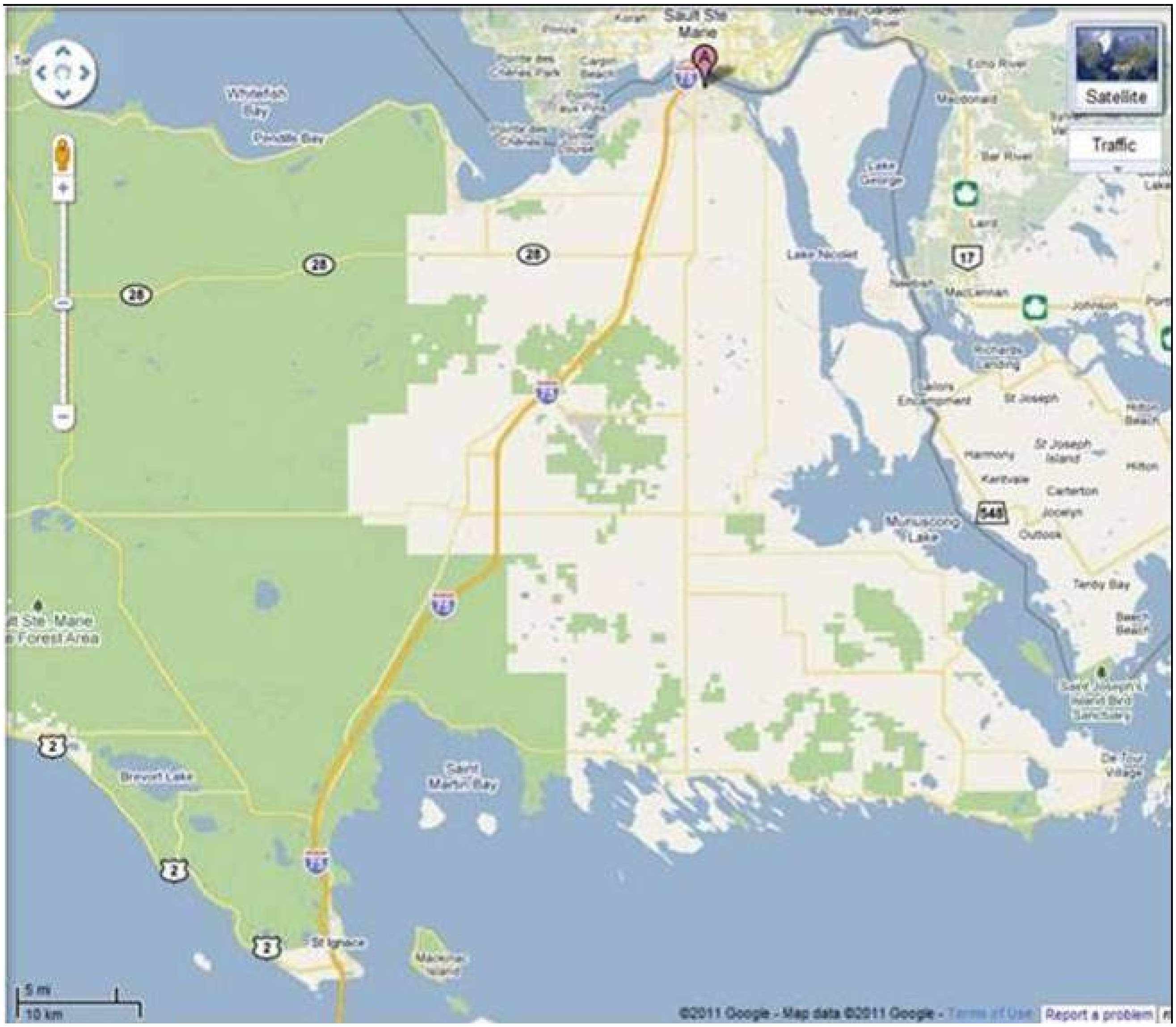

Figure A-1. The eastern Upper Peninsula of Michigan showing Sault Ste. Marie and St. Ignace.

A.3 Area of Demonstration

Figure A-2 depicts the area near the Straits of Mackinac, MI in which the demonstration was performed.

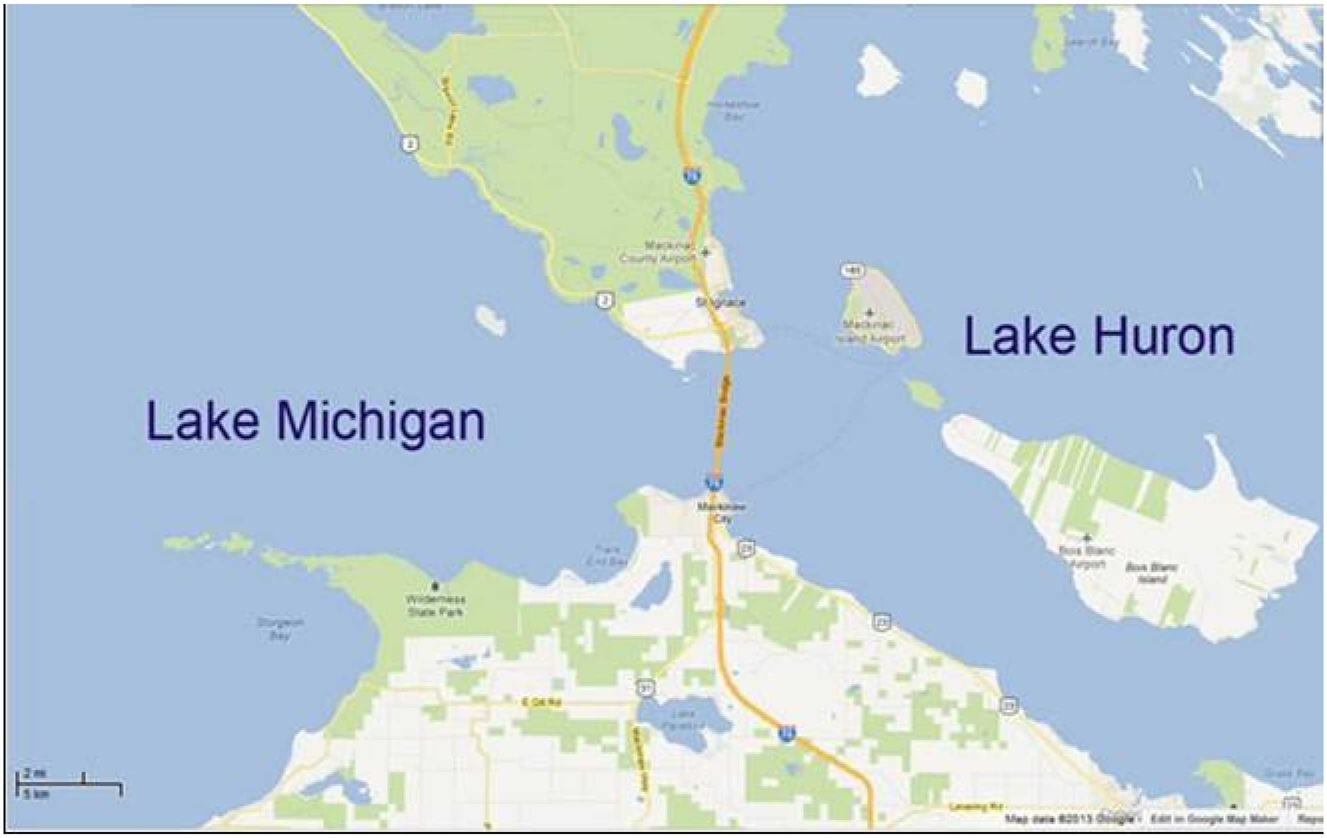

Figure A-2. Straits of Mackinac demonstration operating area.

A.4 CG Station St. Ignace

Figure A-3 shows the pier at CG Station St. Ignace from which the demonstration was staged. The pier was used for loadout and un-load operations as well as for daily mooring of the vessels participating in the demonstration. The CGC Hollyhock was moored to the left side of the pier and the barge and two participating tugboats to the right side.

Figure A-3. CG Station St. Ignace pier (staging location).

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APPENDIX B. OIL RECOVERY SYSTEMS

B.1 Skimmers

B.1.1 DESMI Helix Skimmer

The DESMI Helix circular brush skimmer permits the oil to flow freely onto the brushes from any angle. It is reported to work well with heavy and thick oils that do not flow well. In this implementation, the large area of brushes is in contact with the oil layer, reportedly over 13 linear feet. A hydraulic motor provides power to rotate the brushes. The motor is mounted with a gearbox and a vertical positive displacement pump with a reported flow rate up to 125 cubic meters per hour (m^3/hr) (550 gallons per minute (gpm)) and can develop up to 10 bar (140 pounds per square inch (psi)) discharge pressure. See Figure B-1 and Table B-1.

Figure B-1. DESMI Helix skimmer (left and center), control panel (right).

Table B-1. DESMI Helix skimmer specifications.

Capacity:	100 to 125 m^3/hour (hr), 440 to 550 U.S. gpm
Weight:	150 kilograms (kg)/330 lbs
Max. Discharge Pressure:	10 bar/145 psi
Max. Hydraulic Demand:	160 liters per minute/42 U.S. gpm, 210 bar/3045 psi
Hydraulic Hose:	2 x 3/4”, 1 x 3/8” drain or 2 x 1”, 1 x 3/8” drain plus thruster/module hoses
Dimensions:	83” x 91” x 36”

Manufacturer’s website: http://www.desmi.com/

B.1.2 LRB

The working machine requirements are:

- Hydraulic outlets at the end of the crane arm (180 liters/minute, 210 bar for skimmer and pump)
- Hose fitting on the crane arm (including control cable for remote control)
- Maximum pressure on return line: 15 bar
- Load sensing line at the crane arm end
- Drain line at the crane arm end
- Fitting the bucket skimmer to the crane arm

See Figure B-2 and Table B-2.

Figure B-2. LRB 150 W.

Table B-2. LRB technical specifications.

Length:	1835 millimeter (mm)
Width:	1700 mm
Height:	900 mm
Weight:	900 kg
Design Capacity:	70 m^3/hr
Capacity, Certified Maximum:	115 m^3/h
Free Water Collected:	<5%
Hydraulic Flow (skimmer only):	40 liters/minute
Hydraulic Pressure:	210 bar
Power Requirement:	15 kilowatts (kW)

Manufacturer's website: www.lamor.com

B.2 KMA-333 Hydraulic Submersible Pump

The KMA-333 is a hydraulic submersible axial centrifugal pump was used to provide water to the fire monitor but was originally designed to provide offload for viscous oils or high volume for low viscosity oils. Its narrow profile allows it to pass through openings as small as 12". The KMA-333 was engineered to achieve high flow rates when transferring high-viscosity fluids (oils). The entire system consists of one diesel hydraulic power pack, one KMA-333 pump, one set of discharge hoses, one set of hydraulic hoses, and one LD3 container (modified) with standard accessories kit. See Figure B-3, Table B-3. Table B-4, and Table B-5.

Figure B-3. KMA-333 hydraulic submersible pump shown with diesel hydraulic power pack.

Table B-3. KMA-333 hydraulic submersible pump specifications.

Weight:	~194 lbs
Height:	29.5"
Diameter:	12"
Discharge:	6"
Maximum Capacity:	2,400+ gpm (freshwater)
Maximum Head:	265'+
Hyd. Supply:	Maximum 4,600 psi
Hyd. Return:	250 psi
Hydraulic Flow:	70 gpm (variable)
Connections:	Quick disconnects (1" supply and return, 1/2" case drain)

Table B-4. LMF Series 135 hp diesel hydraulic powerpack.

Weight:	2,900 lbs (wet)
Dimensions:	H 65” x L 95” x W 40”
Engine:	Duetz 6-cylinder turbocharged with integral hydraulic oil cooler
Horsepower (hp):	135-142 hp (continuous)
Fuel:	#2 diesel (5-gallon integral tank with remote supply selector), Oil/Water Separator System
Gauges:	Tachometer, Motor Oil Temp, Motor Oil Pressure, Hydraulic Pressure-Supply, Hydraulic Pressure-Return, Hydraulic Flow, Hydraulic Temperature, Starter Group Hydraulic Pressure
Controls:	Engine Speed, Hydraulic Flow (both controls are variable)
Hydraulic Specifications:	4,600 psi @ 70 gpm (variable)
Connections:	Quick-disconnect (1” supply and return, 1/2” case drain)

Table B-5. Associated KMA-333 transfer and hydraulic hoses.

Discharge Hoses:	6 each, petroleum discharge hose (nitrile), 6” diameter by 50’ length Camlock couplings (stainless steel) maximum allowable working pressure (MAWP) 150 psi: Tested to U.S. Coast Guard (USCG) Standards
Hydraulic Hoses:	5 each, 1” supply (100R12, 5,000 psi MAWP), 1” return (100R2, 2,000 psi MAWP), 1/2” case drain (100R1, 2,000 psi MAWP) Furnished with choice of quick-disconnect couplings
Fuel Hoses:	1 set 1/2” x 15’ fuel transfer hoses (supply and return), quick-disconnect couplings
Basket Weight:	~2,000 lbs (loaded)
Basket Dimensions:	2 @ H 53” x L 53” x W 53”

Manufacturer’s web page: http://www.marinepollutioncontrol.com

B.3 MPC Oil Herding Monitors

See Figure B-4 and Table B-6.


Figure B-4. Oil herding fire monitor close-up (left), fire monitor in operation (right).

Table B-6. Oil herding monitor specifications.

Output Volume:	500 gpm nozzle and 1,000 gpm nozzle
Maximum Output Pressure:	150 psi
Construction:	Painted steel
Intake:	6” camlock
Base:	~42” x 42”
Weight:	Approximately 650 - 750 lbs
Dimensions of Turret, in “Closed” Position:	50” (L) x 40” (W) x 44” (H)
Volume:	58” cube

Manufacturer’s website: http://www.marinepollutioncontrol.com

B.4 American Fireboom MKII System (Practice system)

The American Fireboom MKII Boom System comprises an inflatable boom that is covered with a special fire-resistant material. This material is continually soaked with water internally when in operation. The entire system includes five 100' boom sections, a boom reel, one power unit, and two pumps that can fit inside a 20' "high cube" shipping container. See Figure B-5 and Table B-7.

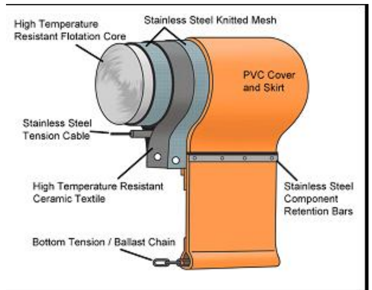



Figure B-5. Complete American Fireboom MKII System in "high cube" shipping container (left), boom cross-section (center), boom deployed and towed by two vessels (right).

Table B-7. System component dimensions.

Reel and Boom:	122 x 89 x 103", 3.09 x 2.26 x 2.61 meters (m), 7,000 lbs, 3,181 kg
Power Unit:	28 x 25 x 29", 0.71 x 0.63 x 0.73 m, 300 lbs, 136 kg
Water Feed Pumps (each):	86 x 54 x 74", 2.18 x 1.37 x 1.88 m, 2650 lbs, 1,202 kg

Manufacturer's website: http://www.elastec.com

B.5 Deep Ocean HD2 Deep Ocean Survey ROV

See Figure B-6 and Table B-8.

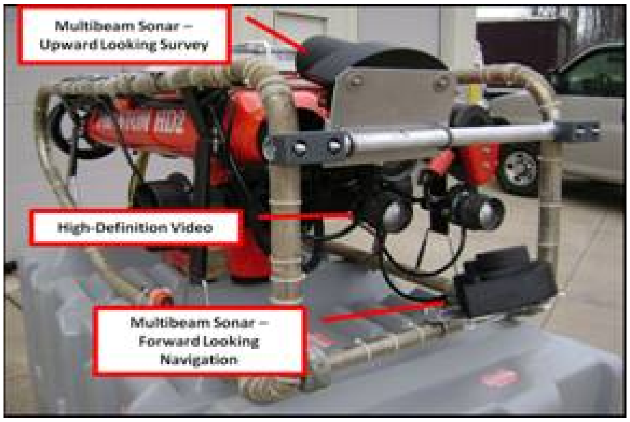


Figure B-6. HD2 ROV (left), on deck.

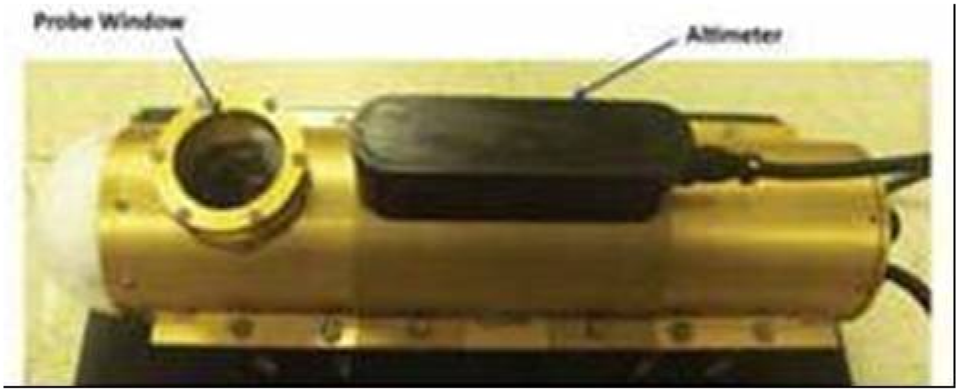
Table B-8. HD2 ROV selected technical specifications.

Weight:	200 lbs
Operating Depth:	1000’
Dimensions:	55” (L) x 27” (W) x 26.5” (H)
Input Voltage:	100 - 250 volts alternating current (VAC)
Frequency:	50/60 Hertz (Hz)
Power Rating:	4.5 kilovoltampere (kVA)
Umbilical Tether Lengths:	550’, 1100’, 2100’

Manufacturer’s website: http://www.deepocean.com

B.6 EIC Laboratories Fluorescence Sensor for Locating and Tracking Submerged Oil

EIC Laboratories has developed Oscar™, an underwater fluorescence polarization sensor for detecting submerged oil on the sea floor and in the water column. This device had been expected to be deployed on an ROV/AUV to operate beneath ice sheets and rubble ice. See Figure B-7 and Table B-9. The company has developed a scanning system that moves the laser light back and forth rather than staying as a pencil beam. Due to the damage to the probe window, this was demonstrated in air in one of the vessels compartments.



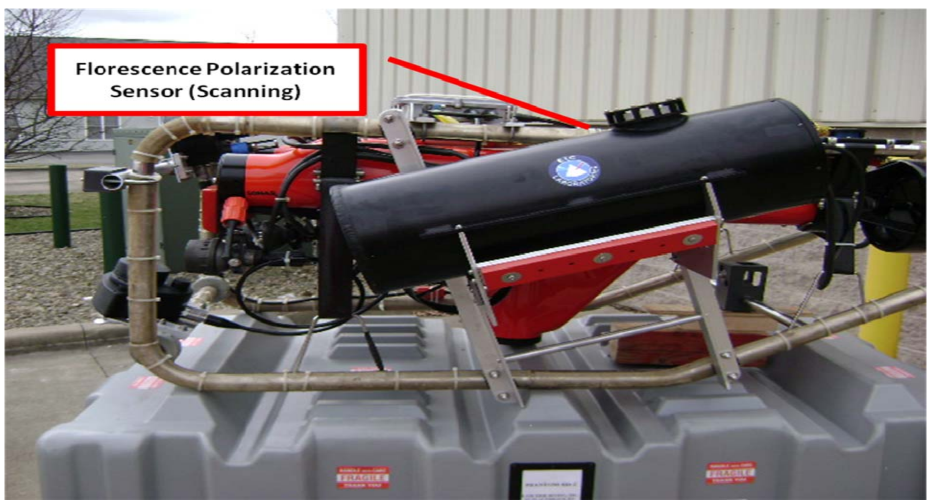


Figure B-7. Original Oscar fluorimeter showing optical window and attached altimeter (top) and scanning version mounted on ROV (Bottom).

Table B-9. EIC Laboratories Oscar specifications.

Length:	20”
Diameter:	4.5”
Weight:	16 lbs
Power:	31 watts at 24 volts direct current (VDC)
Rated Operating Depth:	200’

Manufacturer’s website: http://www.eiclabs.com/

B.7 Norbit Imaging Echo-sounder

Norbit has a wide-band multi-beam imaging echo-sounder that employs active acoustics to detect oil in the water volume. The sensor is designed to fit on a multitude of different platforms both stationary and moving. This device had been expected to be deployed on an ROV/AUV to operate beneath ice sheets and rubble ice. See Figure B-8 and Table B-10.

Figure B-8. Norbit FLS Dual Head set-up (left), associated surface instrumentation and control (right).

Table B-10. Norbit specifications.

Weight:	2 kg
Power:	25 watts

Manufacturer's website: http://www.norbit.no

B.8 Fassi Crane Model 130 AFM.23

See Table B-9, Table B-11, and Table B-12.


Figure B-9. Fassi crane in operation (left), Fassi crane and power pack on a 10’ flat rack (right).

Table B-11. Fassi Crane Model 130-AFM.23 general specifications.

Lifting Capacity:	11.9 tons metric (tm)
Standard Reach:	10.40 m
Hydraulic Extension:	5.70 m
Rotation:	390 degrees
Rotation Torque:	21.50 kilo Newton-meters (kNm)
Working Pressure:	28.50 micropascal (μPa)
Pump Capacity:	40 liters/minute
Oil Tank Capacity:	90 liters
Crane Weight:	1910 kg
Crane Length:	2400 mm
Crane Width:	830 mm
Crane Height:	2205 mm

Table B-12. Fassi 10’ flat rack general specifications.

Length:	2990 mm
Width:	2435 mm
Height:	2518 mm (with equipment)
Weight Empty:	1020 kg
Equipment Weight:	3240 kg
Total Weight:	4260 kg (container + equipment)

Manufacturer’s website: http://www.fascan.com/

B.9 Rutter Sigma 6 Oil Spill Detection System

The Sigma S6 Oil Spill Detection (OSD) system automatically detects oil, day and night and in low and poor visibility conditions. It provides real-time imaging, and tracking and vector information of the spill on both shipboard and platform installations. With a simple-to-use radar display, the OSD can be implemented as a stand-alone system or integrated into a data and image sharing network for large-scale response operations. Benefits include: automatic alarm and outlining, motion compensation for mobile applications, dedicated functions for detection and continuous real-time monitoring, and integration with a wide range of navigational radars and multiple polarized antenna arrays. See Figure B-10, Figure B-11, and Table B-13.

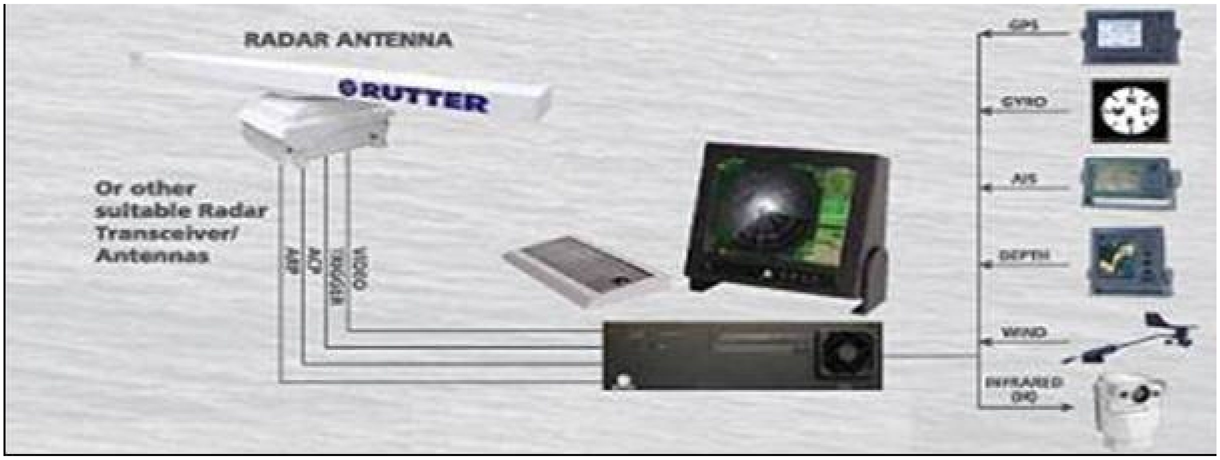


Figure B-10. Block diagram of SIGMA 6 Oil Recovery System.

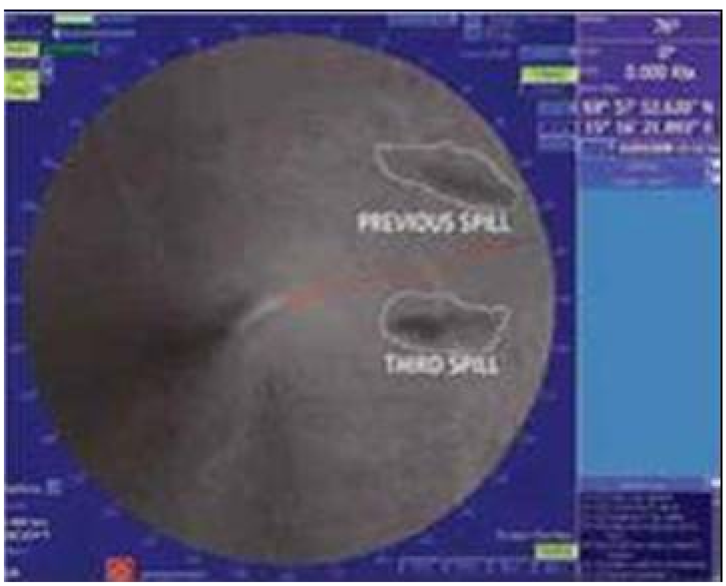


Figure B-11. Annotated representation of SIGMA 6 system output.

Table B-13. Sigma 6 OSD System selected system specification.

Source Radar Requirements:	X-Band, 25 kW, 3 kilohertz (kHz) pulse repetition frequency, 1 degree antenna beamwidth, > 40 revolutions per minute (rpm) antenna rotation speed
Radar Interface:	Raw video, trigger heading, antenna rotation
Radar Input Data Interfaces (NMEA RS422):	GPS, gyro compass, Automatic Identification System (AIS), anemometer, depth sounder
Data Output Interface (NMEA RS422):	TTM (Tracked Target Message) or RSD (Radar System Data), cursor

Manufacturer's website: http://www.rutter.ca/

B.10 Woods Hole Oceanographic Institute (WHOI) AUV

SeaBED's twin-hull design stands in stark contrast to that of most commercial "torpedo-shaped" AUVs, but provides greatly enhanced stability for low-speed photographic surveys. SeaBED is approximately 2 m long and weighs nearly 200 kg. The vehicle has two main pressure housings containing the electronics and the batteries. The electronics are located in the top hull, and connected to the batteries and sensors in the bottom hull by wet cabling routed through the vertical struts. SeaBED is equipped with an RDI Workhorse Navigator Acoustic Doppler Current Profiler (ADCP) for bottom-locked navigation, an Imagenex Delta-T imaging sonar for bathymetry capture, and a custom camera system based on high-dynamic range Prosilica cameras. It also has a WHOI MicroModem for acoustic communication and navigation, and a Sea-Bird conductivity/temperature/depth (CTD) sensor for measuring salinity and water temperature. The main computer is a 1.2 gigahertz (GHz) Pentium processor, running Ubuntu Linux 8.04. The custom vehicle software is primarily written in the C programming language. See Figure B-12.

Figure B-12. SeaBED AUV being deployed.

B.11 Inland-Gulf Maritime Aerostat IC

The Aerostat IC is a helium-filled aerial platform (Figure B-13) that deploys fully integrated surveillance sensors. The views of the IR and visual views can be transmitted wireless to line-of-site locations on other vessels or on land. It comes in its own package complete with helium and a winch system. The shipped package weighs about 2800 lbs with the helium bottles loaded or about 1600 lbs without helium. It is 7.2' long, 5.6' wide, and 6' high.

Figure B-13. Aerostat IC.

- Aerostat IC (Balloon)
  - Manufactured from dual-ply urethane-impregnated fabric
  - Volume: 39.6 m3 (1400 cubic feet)
  - Diameter: 4.58 m (15')
  - Height: 3.35 m (11')
  - Maximum Altitude: 1000' above ground level (AGL)
  - Gross Static Lift: 25 kg (55 lbs)
  - Net Static Lift: 15.8 kg (35 lbs)
- Operations
  - Set-up and inflation: < 30 minutes
  - Deployment to 1000': < 20 minutes
  - Recovery from 1000': < 20 minutes
  - Maximum Time Aloft without Service (weather permitting): 4 days; depending on payload, it can be longer)
  - Helium servicing: < 20 minutes
- Limitations
  - Operational Maximum Wind aloft: 40 kts
  - Survivable Maximum Wind aloft: 60 kts
  - Maximum Aerostat IC Altitude: 1000' AGL
- Emergency Deflation Device
  - A remote radio-controlled burn unit which can be activated up to 5 miles and, when actuated in case of emergency, will burn a 6" hole on the top of the Aerostat IC, thus releasing the helium and deflating it within seconds

APPENDIX C. MANUFACTURERS' EQUIPMENT LITERATURE

Literature and brochures for the specific equipment used in this demonstration are available at the following manufacturers' websites.

- **DESMI Helix skimmer:** http://www.desmi.com/UserFiles/file/oil%20spill%20response/e-leaflet/05-15%20HELIX%20SKIMMER.pdf
- **Deep Ocean HD2 ROV:** http://www.divetechltd.ca/hd2.pdf
- **Lamor Bucket Skimmer:** http://www.lamor.com
- **SeaBED AUV:** http://www.whoi.edu/main/seabed
- **Inland-Gulf Maritime Aerostat IC:** http://www.inland-gulf.com/
- **Rutter Sigma 6 Oil Spill Detection System:** http://http://www.rutter.ca/
- **Fassi Crane:** http://www.fascan.com/
- **MPC Oil Herding Monitor:** http://www.marinepollutioncontrol.com
- **American Fireboom MKII System:** http://www.elastec.com
- **EIC Laboratories Fluorescence Sensor for Locating and Tracking Submerged Oil:** http://www.eiclabs.com/
- **Norbit Imaging Echo Sounder:** http://www.norbit.no

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APPENDIX D. PARTICIPATING VESSEL SPECIFICATIONS

WLB Hollyhock

Figure D-1. WLB Hollyhock and full tank arrangement.

Vessel Particulars:

Class & type:	Juniper
Displacement:	2,000 long tons (2,000 t) at design draft (full load)
Length:	225’ (69 m)
Beam:	46’ (14 m)
Draft:	13’ (4.0 m)
Propulsion:	2 × 3,100 shaft horsepower (shp) (2,300 kW) Caterpillar diesel engines
Speed:	15 kts (28 kilometers per hour (km/h); 17 mph) at full load displacement (80% rated power)
Range:	6,000 nm (11,000 km; 6,900 miles) at 12 kts (22 km/h; 14 mph)
Complement:	50 (8 officers, 42 enlisted)

T/V Nickelena (U.S. Registry)

Figure D-2. T/V Nickelena (U.S. Registry).

Vessel Particulars:

Length:	108’
Beam:	29’
Draft:	14’
Gross Tons:	199
Horsepower	2000
Flag:	U.S.
Propulsion:	“infinite” variable drive with bow thrusters

Nickelena Other Features

- Crane, approximately rated for 3,000 lbs capable of deploying equipment from the deck to the water.
- Anchoring capability and GPS to maintain position.
- Tug has AIS.

Tug company web page: http://www.basicmarine.com/transportation/

T/V Erika Kobasic (U.S. Registry)

Figure D-3. T/V Erika Kobasic (U.S. Registry).

Vessel Particulars:

Length:	110’
Beam:	25’
Draft:	12’
Gross Tons:	226
Horse Power:	2000
Flag:	U.S.
Built;	1939
Propulsion:	“infinite” variable drive with bow thrusters

Other Features:

- Crane, approximately rated for 3,000 lbs capable of deploying equipment from the deck to the water.
- Anchoring capability and GPS to maintain position.
- Tug has AIS.

Tug company web page: http://www.basicmarine.com/transportation/

Barge

Type of barge to be used in the demonstration

Figure D-4. Barge.

<u>Barge Particulars:</u>

Length:	220’
Beam:	55’
Draft:	12’
Gross Tons:	1077.7
Horsepower	N/A
Flag:	U.S.
Propulsion:	N/A

<u>Other Features:</u>

- 4300 lbs/ft^2 deck loading
- 4/40’ spuds
- 100-ton ramp
- Ballasting system

Barge company web page: http://www.basicmarine.com/transportation/

Barge Deck Crane

Type of crane to be deployed on barge

Figure D-5. Barge deck crane

Crane Particulars:

- Grove RT875 (75-ton "cherry picker")
- 100' boom (40' jib and 60' main)

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APPENDIX E. DEMONSTRATION PARTICIPANTS AND POINTS OF CONTACT

Table E-1. Demonstration participants and points of contact.

Name	Agency
State/Local Representatives	
Les Therrian	St. Ignace Town Manager
Mike Kasper	Director of Mackinac County Emergency Services
U.S. Government Representatives	
Kurt Hansen	RDC
Mike Coleman	RDC
Scott Fields	RDC
Alex Balsley	RDC
John McLeod	RDC
Danielle Elam	RDC
Joel R. Brooks, MKC	Atlantic Strike Team
Christopher P. Hinsch ENG3	Gulf Strike Team
Jason Rizzi , MSSE2	Pacific Strike Team
Matt Reisinger, BM1	Station St. Ignace
Michael Beatty, BMCS (Officer in Charge (OIC))	Station St. Ignace
Steve Keck	Sector Sault Ste Marie (SSM)
Mike Thompson, ENS	Sector Sault Ste Marie (SSM)
Robert Rosenow, LCDR	Sector Sault Ste Marie (SSM)
David Faith, MKC	Sector Sault Ste Marie (SSM)
YN1 Julie Bosman	Sector Sault Ste Marie (SSM)
MST2 Kevin Moe	Sector Sault Ste Marie (SSM)
Brian Streichert	Sector Sault Ste Marie (SSM)
LCDR Nick Wong	Sector Sault Ste Marie (SSM)
LTJG Mike Thompson	Sector Sault Ste Marie (SSM)
MST2 Kevin Moe	Sector Sault Ste Marie (SSM)
MST1 Thomas Link	Sector Sault Ste Marie (SSM)
MST3 Nolasco	Sector Sault Ste Marie (SSM)
MST3 Gambino	Sector Sault Ste Marie (SSM)
Mark Wagner	D17 JUNEAU, DRAT
Matt Odum	D17 JUNEAU, DRAT
Alvin (Mike) Crickard	NSFCC (NC)
Sara Booth, LT	CG-MER-3
Amy McElroy, LT	CG-MER-1
James Longton, ENG3	CG-432-C
Binko Scott, GS 9	D9 Cleveland
Stephen Torpey, CAPT	D9 Cleveland
Mary Hoffman, LT	D9 Cleveland
Anthony Mangoni	D9 Cleveland
David Lieberman, LTJG	D9 Cleveland
Greg Woll, MST2	D9 Cleveland

Table E-1. Demonstration participants and points of contact (Continued).

Name	Agency
U.S. Government Representatives (Continued)	
Bob Allen	D9 Cleveland9
Colby Schlaht, LT	D9 Cleveland
CDR Tim Brown	CO CGC Hollyhock
LTJG Alexander Fulton	OPS CGC Hollyhock
Jay Lomnicky, LCDR	NOAA
Frank Winingham	Occupational Safety & Health Administration (OSHA)
Derek Hardy, MSTC	TRACEN Yorktown
Terry Hasenauer, MST1	TRACEN Yorktown
Lawrence DiDomenico	MSU Duluth, MN
MST1 Caleb Peterson	MSU Duluth, MN
Observers	
Stephanie Gandulla	Thunder Bay National Marine Sanctuary
Jeff Gray	Thunder Bay National Marine Sanctuary
Russ Green	Thunder Bay National Marine Sanctuary
Sarah Waters	Thunder Bay National Marine Sanctuary
Gabe Schneider	Regional Rep for US Senator Carl Levin
Dr. Olin Joynton	President, Alpena Community College
David Cummins	Marine Technology Advisor, Alpena CC
Don MacMaster	Dean of Workforce Development, Alpena CC
Adam Wojciehowski	Response & Security Coordinator - U.S. Operations | Enbridge Energy
Anthony (Tony) Parkin	Oil Spill Planning Advisor, BPXA
Regina Ward	Crisis Management Advisor, BPXA
Direct Government Contractors	
Bert Yankielun	SAIC
Ed Cables	SAIC
Rick Barone	SAIC
Chris Locklear	SAIC
Brad Wilson	SAIC
Lead Equipment and Support Contractors	
Bill Hazel	Marine Pollotion Control
Joe Calcaterra	Mackinac Environmental Serv (MPC)
Shon Mosier	Elastec American Marine
Pat Murphy	Lake Erie Diving
Hanumant Singh	Woods Hole Oceanographic Institute
Peter Eriksen	NORBIT
Dr. Job Bello	EIC Laboratories
Brian Johnson	Rutter
Vince Mitchell	LAMOR
Chris Wiggins	Inland Gulf
Ken Hartman	Applied Fabrics
Capt Daniel Voss	Salvation Army

APPENDIX F. ENVIRONMENTAL PERMISSION LETTER

RICK SNYDER
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

DEQ

DAN WYANT
DIRECTOR

November 7, 2012

Mr. Kurt A. Hansen, P.E.
U.S. Coast Guard
Acquisition Directorate Research and Development Center
1 Chelsea Street
New London, Connecticut 06320

Dear Mr. Hansen:

Enclosed please find the Michigan Department of Environmental Quality (MDEQ) Certification of Approval issued pursuant to Rule 97 of Michigan's Water Quality Standards, authorizing your October 16, 2012, request to place small amounts of oranges and peat moss into the Mackinac Straits in February 2013. The operation is intended to model oil spill response.

MDEQ authorization is contingent upon the U.S. Coast Guard complying with specific procedural and reporting requirements described by the enclosed Rule 97 Certification. Please review the conditions of the Certification of Approval carefully prior to commencing the operation.

Please contact me if further assistance or information is needed.

Sincerely,

William F. Dimond, Aquatic Biology Specialist
Surface Water Assessment Section
Water Resources Division
517-241-9565

Enclosure
cc/enc: Mr. Steve Casey, Upper Peninsula District Supervisor, MDEQ
Mr. Brian Jankowski, Cadillac District Supervisor, MDEQ
Ms. Diana Klemans, MDEQ
Mr. Dennis Bush/Rule 97 File, MDEQ

CONSTITUTION HALL • 525 WEST ALLEGAN STREET • P.O. BOX 30473 • LANSING, MICHIGAN 48909-7973
www.michigan.gov/deq • (800) 662-9278

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
CERTIFICATION OF APPROVAL

In compliance with the provisions of Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, and Rule 97 of the Water Quality Standards, the U.S. Coast Guard is granted approval to place small quantities of oranges and peat moss into the Mackinac Straits consistent with the requirements of this certification. The operation is intended to model oil spill response, with the oranges and peat moss acting as oil surrogates.

Approval is based on the October 16, 2012, request by Mr. Kurt A. Hansen, U.S. Coast Guard, submitted to Ms. Diana Klemans, Chief, Surface Water Assessment Section, Water Resources Division (WRD), Michigan Department of Environmental Quality (MDEQ). Authorization is contingent upon full compliance with the following requirements:

1. Placement of surrogates shall take during February 2013.
2. Placement of surrogates shall be minimized to the extent practicable.
3. Surrogates shall be recovered to the extent practicable.
4. The U.S Coast Guard shall notify Mr. Brian Jankowski, Cadillac District Supervisor, WRD, MDEQ, at 231-876-4474, and Mr. Steve Casey, Upper Peninsula District Supervisor, WRD, MDEQ, at 906-346-8535, a minimum of ten days prior to the operation.
5. In the event that any of the above conditions of this Certification of Approval are or may not be met, the U.S Coast Guard shall immediately notify Mr. Brian Jankowski and Mr. Steve Casey, WRD, MDEQ.
6. The issuance of this Certification of Approval does not authorize violation of any federal, state, or local laws or regulations, nor does it obviate the necessity of obtaining such permits, including any other MDEQ permits, or approvals from other units of government as may be required by law.

Issued this 7th day of November 2012, by the MDEQ and shall expire March 1, 2013.

William F. Dimond
Aquatic Biology Specialist
Surface Water Assessment Section
Water Resources Division
517-241-8505

APPENDIX G. OIL-IN-ICE TACTICS

These tactics are based on information found in: Alaska Clean Seas Technical Manual (Reference 3) and the STAR Manual (Reference 4). Time and ice conditions permitting, these served as guidelines for tactics applied during the St. Ignace demonstration.

Contents

1. OPEN WATER CONDITIONS

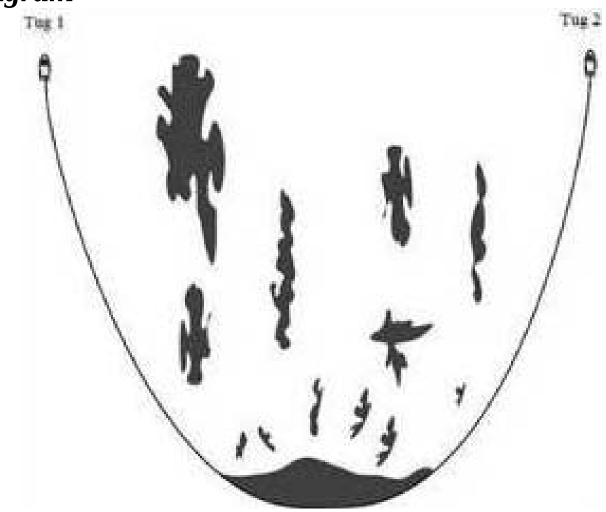
Open Water – In Situ Burning (ISB)

ISB is a technique to remove oil from the surface of the water before it reaches the ice or shoreline. Vessels must capture the oil and tow it to a safe location (defined by the Federal On-Scene Coordinator (FOSC) with respect to water depth, smoke plume, and distance from population and other responders) while moving at less than 1 kt. This tactic is enhanced if the wind is blowing away from populated areas and if the collected oil forms a thick enough layer (>2-3 mm) so it will burn better.

Deployment Considerations and Limitations

There are two types of fire-resistant boom. One type is lighter weight and is built of fire-resistant material and shaped like a standard boom. Short sections can be temporarily stored on a vessel's deck. A water-cooled boom normally is shipped on a large reel that needs power and deck space for deployment. It also has two water pumps that need to be placed on the towing vessels. Special care may be needed to ensure the waterlines do not freeze during cold weather conditions. The hoses could be more susceptible to damage from ice or vessel propellers. Boom may be deployed from either a staging platform such as a barge or the towing vessels. However, in either case a very large deck space is necessary to stow the boom before deployment. Deployment typically involves towing the length of faked-out boom into the water from the deck and then to the start position, where another tug retrieves the other end of the boom. Experience shows the boom should not be deployed in heavy ice conditions as damage is likely to occur to the boom and its associated towing lines or water hoses. For this reason, ice conditions should not exceed more than about 20% of coverage. Depending upon boom weight, environmental conditions, and staffing levels, a crane or boom is typically necessary in order to recover the boom not otherwise destroyed in the ISB process. Hand tools and heating devices are needed to assemble and disassemble mechanical or frozen fittings.

Tactic Diagram



Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Tugboat 1	Tow boom	1-2	1 (2*)	#	#
Tugboat 2	Tow boom	1-2	1(2*)	#	#
Crane	Recover boom	1	1	#	1-2 hours
Fire-resistant Boom	Containment, ISB	1	N/A	4 days	2 hours

*For water-cooled
depends upon location

Open Water – Skimming Operation

Mechanical containment and recovery at lakes or seas depend on the wave and wind conditions at the spill site. Wave heights exceeding 2 m and wind speed greater than 35 km/h will restrict responders from deploying skimmers as a response strategy. This tactic may involve a skimmer deployed from a cutter or large vessel using a single boom or crane, excavator oil bucket/boom assemblies, or similar configuration. When it is feasible to do so, containment booms can be deployed to intercept, control, and recover thicker slicks. The cutter/vessel movement is directed by aerial support to find and recover as much oil as they can while deployed.

Deployment Considerations and Limitations

Hydraulic hoses and recovery hoses may be susceptible to damage if dragged over or through ice. Pieces of ice can block the oil from reaching the inlet. Adequate water supply tanks, hoses, and heating systems may be needed on certain configurations. Long lengths of hose running over the deck may need to be heated to prevent freezing. Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs.

Tactic Diagram

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Operational Vessel	Working platform	1	4	#	#
Skimmer	Recovery	1-2	2-4	2-3 hours	30 minutes

depends upon location

Open Water – Herding

Herding is designed to move the oil slick into an area where it can be burned, contained, or recovered. It is usually done with a fire monitor that can move oil from a fixed location into a preferred area. In the open water, it is useful in gathering up wayward slicks into one mass for an easy recovery operation. Mounting the unit on the vessels' bow is preferred for control and visibility. At least two vessels are needed for open water.

Deployment Considerations and Limitations

Care should be taken not to send water directly into the oil or with too much force that can push the oil under the ice. The water stream should be directed at least 10-20' from the oil and the movement of the local water used to control the oil movement. Care for preventing freeze-up should also be taken if the system is off. Any use of antifreeze must comply with local regulations. Intakes and hoses that go over the side may be exposed to ice that can damage or disable equipment. The boom can be deployed alongside an ice edge if the ice is not clearly defined and the weather is reasonable. An additional boom can be deployed from the collection vessel or barge to help concentrate the oil.

Apparatus Mounted on a Tugboat

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Tugboat	Working platform	1	2	#	#
Fire Monitor	Herd oil	1	2	2 hours	5 minutes

depends upon location

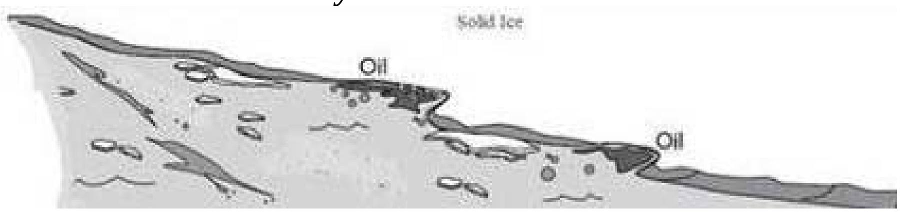
Open Water – Finding Collection Points

During most times of the year, oil gathers in natural collection points along the shoreline in locations where the current and waves are minimal. In ice conditions, oil also moves to these types of areas. Using the ice as a natural barrier for containment is crucial for recovery without pushing the oil below or on top of the ice. This is the first priority for utilizing the other recovery techniques.

Deployment Considerations and Limitations

During some months, some debris may be floating on the water inside of the oil. Care should be taken as animals may also take advantage of these places.

Finding Collection Points: Oil Collection Pockets on an Open Water/Sheet Ice Boundary



2. ICE EDGE CONDITIONS

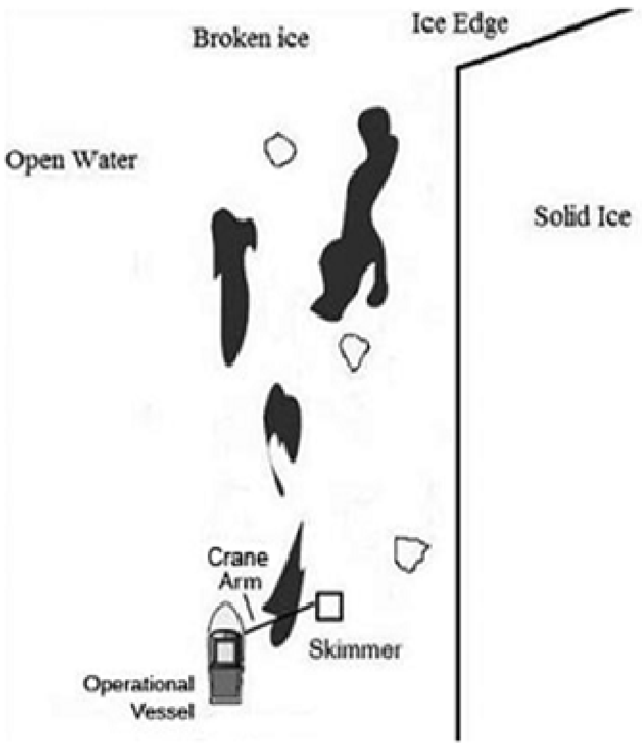
Ice Edge – Skimming Operation

Mechanical containment and recovery at lakes or seas depend on the wave and wind conditions at the spill site. Wave heights exceeding 2 m and wind speed greater than 35 km/h should restrict responders from deploying skimmers as a response strategy. Skimmers are deployed from a cutter or large vessel using a single boom or crane. When feasible to do so, containment booms can be deployed to intercept, control, and recover thicker slicks. The cutter/vessel movement is directed by aerial support to find and recover as much oil as they can while deployed. This tactic may involve floating skimmers deployed from a cutter or large vessel using a single boom or crane, excavator oil bucket/boom assemblies, or similar configuration.

Deployment Considerations and Limitations

Hydraulic hoses and recovery hoses may be susceptible to damage if dragged over or through ice. Pieces of ice can block the oil from reaching the inlet. Hydraulic hoses and recovery hoses may be susceptible to damage if dragged over or through ice. Pieces of ice can block the oil from reaching the inlet. Adequate water supply tanks, hoses, and heating systems may be needed on certain configurations. Long lengths of hose running over the deck may need to be heated to prevent freezing. Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs.

Tactic Diagram



Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Operational Vessel	Working platform	1-2	2-4	4-6 hours	1-2 hours
Tugboat	Working platform	1	2-3	2-3 hours	<1 hour
Skimmer	Recovery	1-2	2-4	2-6 hours	< 1 hour

Ice Edge – Herding

Herding is designed to move the oil along the ice to a collection point or to help concentrate near a skimmer. It is usually done with a fire monitor that can move oil into a preferred area.

Deployment Considerations and Limitations

Care should be taken not to send water directly into the ice or with too much force that can push the oil under the ice. The water stream should be directed at least 10-20’ from the ice and the movement of the local water used to control the oil movement. Care for preventing freeze-up should also be taken if the system is off. Any equipment placed over the side can be exposed to ice that can damage or disable the equipment.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Vessel	Working platform	1	2	#	#
Fire Monitor	Herd oil	1	2	2-4 hours	<1 hour

depends upon location

Ice Edge – ROV/AUV

This technique uses an ROV or AUV to search near the ice edge to look for oil that is under the ice. It could also be used down a hole if the ice is solid and personnel are deployed on the ice. Sensors that can be deployed include cameras, sonar, or fluorometers. Most are configured in a looking-up position. Use of an AUV means that open water must be available during the full timeframe of the deployment to ensure successful recovery.

Deployment Considerations and Limitations

Care needs to be taken to ensure that cables do not get tangled into propellers or bow thrusters. Cables may also be susceptible to damage from the ice. In shallow water, care should be taken not to drag the cable on the bottom. Bright sunlight can help and hinder upward-looking sensors. For thin ice, the ROV may need to be deployed at a deeper depth. Lights may be needed on overcast days and at night. The weight of the system may necessitate the use of a crane, so the vessel selected should have this capability.

ROV in Process of Being Deployed

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Vessel	Working platform	1	2	#	#
ROV	Search	1	2	1-2 hours	<10 minutes

depends upon location

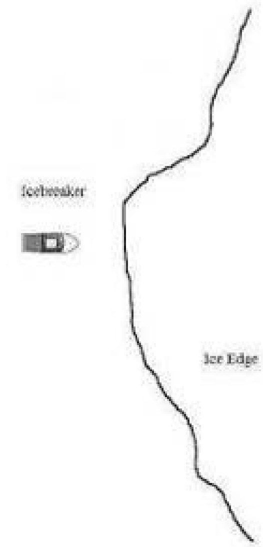
Ice Edge – Ice Management

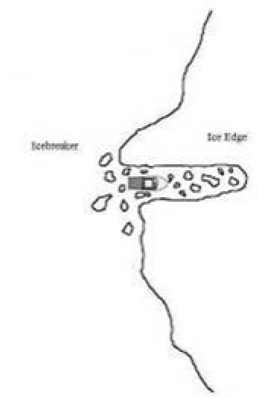
There may be many instances when the management of ice is required either to gain access to the oil or to keep ice away from the oil. Potential tactics include using vessels to move or deflect ice and creating collection slots for oil to surface. Consider how the ice and currents are moving so that any oil is deflected into the slot.

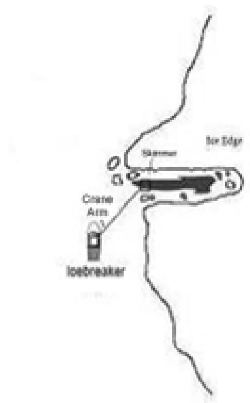
Deployment Considerations and Limitations

The vessel used must have the correct ice classification and operator expertise before using this technique. Multiple vessels could be involved in this tactic, some of which may not have skimming capability.

Vessel Being Used to Create Collection Slot Allowing Oil to Concentrate







Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Ice-capable Vessel	Working platform	1	2	#	#
Skimmer	Search	1	2	1-2 hours	<10 minutes

depends upon location

Ice Edge – Under Ice Retrieval

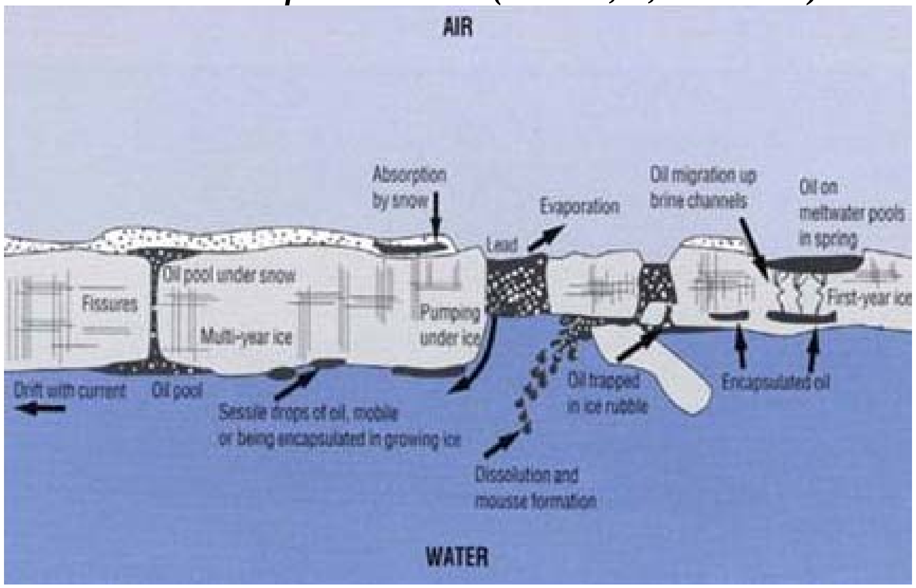
If capable, the ROV or diver could be utilized to dive under the ice with an appropriate suction hose to find and recover oil before it gets to the shoreline.

If the ice is not strong enough for personnel, techniques are needed that can permit an ROV or other mechanism to reach under and recover oil that is under the ice. Most current techniques assume that equipment and personnel can be deployed onto the ice but additional options are needed to deploy from vessels.

Deployment Considerations and Limitations

Use of divers in harsh situation should be closely monitored. Qualified individuals and companies should be selected. Recovery hoses should have added buoyancy that can be adjusted as they fill up with recovered oil. Safety measures should be in place for quick disconnection of the diver or ROV from the hose. A method for temporary storage is needed that is able to handle the expected amount of oil and water.

Potential Locations of Oil Under Ice (Dickens, D, OTC22126)



<u>Equipment and Personnel</u>

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Vessel	Working platform	1	2	#	#
ROV	Search	1	2-4	1-2 hours	<30 minutes

depends upon location

3. BROKEN ICE CONDITIONS

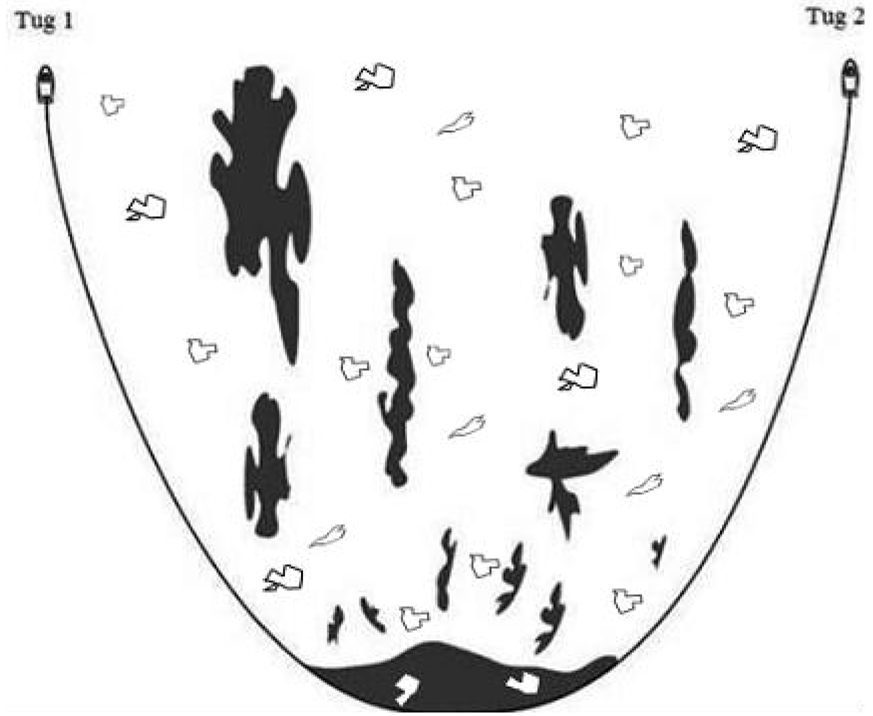
<u>Broken Ice Conditions – ISB</u>

ISB is a technique to remove oil from the surface of the water before it reaches the ice or shoreline. Vessels must capture the oil and tow it to a safe location (defined by the FOSC with respect to water depth, smoke plume, and distance from population and other responders) while moving at less than 1 kt. Broken or brash ice may be collected along with the oil but vessels do their best to avoid amassing a large number of ice pieces. This tactic is enhanced if the wind is blowing away from populated areas and if the collected oil forms a thick enough layer that would burn better. The figure illustrates broken ice conditions with the ISB boom encircling the brash ice. The table lists oil collection assets and deployment data for application of the fire boom. In areas where the broken ice is large and tightly packed, ISB is employed by using the ice as a natural barrier against which the oil concentrates.

<u>Deployment Considerations and Limitations</u>

The boom may be deployed from either a staging platform such as a barge or the towing vessels. However, in either case a very large deck space is necessary to stow the boom before deployment. Deployment typically involves towing the length of faked-out boom into the water from the deck and then to the start position, where another tug retrieves the other end of the boom. Experience shows the boom should not be deployed in heavy ice conditions as damage is likely to occur to the boom and its associated towing lines or water hoses. For this reason, ice conditions should not exceed more than about 20% of coverage. Depending upon boom weight, environmental conditions, and staffing levels, a crane or boom is typically necessary in order to recover the boom not otherwise destroyed in the ISB process. Hand tools and heating devices are needed to assemble and disassemble mechanical or frozen fittings.

Broken Ice Conditions with ISB Boom Encircling Brash Ice



Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Tugboat 1	Tow boom	1	2	#	1-2 hours
Tugboat 2	Tow boom	1	2	#	1-2 hours
Crane	Recover boom	1	1	#	1-2 hours
Fire Boom	Containment, ISB	1	2-4	#	1-2 hours

depends upon location

Broken Ice Conditions – Skimming Operation

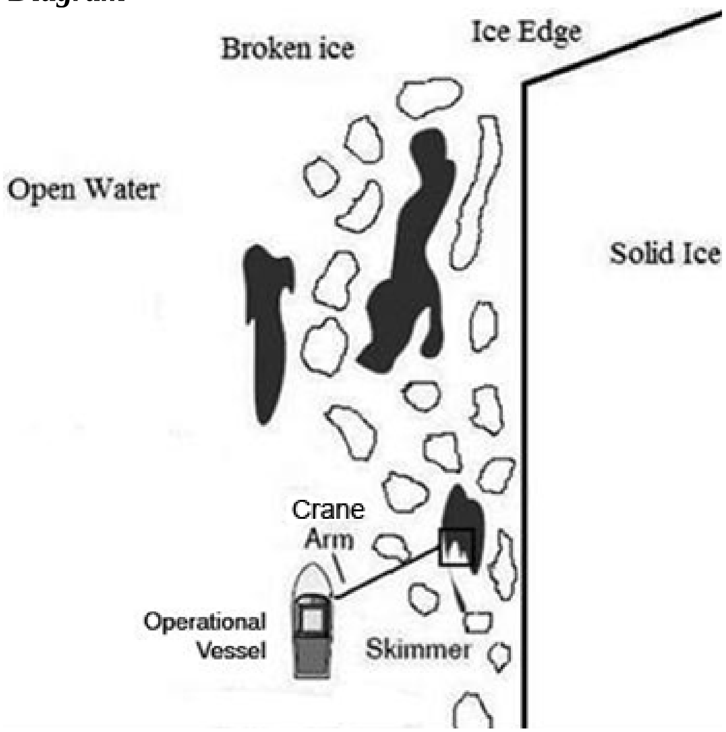
Mechanical containment and recovery at lakes or seas depend on the wave and wind conditions at the spill site. Wave heights exceeding 2 m and wind speed greater than 35 km/h should restrict responders from deploying skimmers as a response strategy. This tactic may involve floating skimmers deployed from a cutter or large vessel using a single boom or crane, excavator oil bucket/boom assemblies, or similar configuration. When it is feasible to do so, containment booms can be deployed to intercept, control, and recover thicker slicks. The cutter/vessel movement is directed by aerial support to find and recover as much oil as they can while deployed. In broken ice, the vessel must try to get as close to an area of collected oil and use the boom/crane to place the skimmer in an area not occupied by ice. It must be carefully monitored so that it is not crushed by the bigger ice floes.

Deployment Considerations and Limitations

The vessel chosen should have the appropriate ice classification and manning to perform this. The vessel should also be able to handle temporary storage. Adequate water supply tanks, hoses, and heating systems may be needed on certain configurations. Long lengths of hose running over the deck may need to be heated to prevent freezing. Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs. The use of an oil recovery bucket/boom assembly securely mounted to the deck of a barge and pushed by a towboat works well in these circumstances in terms of maneuverability. Comparatively, skimmers that use a tether system and that are deployed over the side may present challenges in terms of maneuverability.

Broken Ice Conditions – Herding

Tactic Diagram



Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Operational Vessel	Working platform	1	2	#	1-2 hours
Tugboat	Working platform	Optional	#	#	#
Skimmer	Recovery	1-2	2-4	#	<30 minutes

depends upon location

Herding is designed to move the oil slick into an area where it can be burned, contained, or recovered. It is usually done with a fire monitor that can move oil from a fixed location into a preferred area. Oil can be trapped in small spaces between bits of rubble ice, proving it to be inefficient for burning or collection by oil skimmers. It needs to be transported towards a more open area that is reachable by responders to conduct their recovery operations. Use of a robust skimmer is needed at the collection point. Oil may also get on top of the ice and can be washed off.

Deployment Considerations and Limitations

Care should be taken not to send water directly into the ice or with too much force that can push the oil under or onto the ice. The water stream should be directed at least 10-20’ from the ice and the movement of the local water used to control the oil movement. Care for preventing freeze-up should also be taken if the system is off.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Vessel	Working platform	1	2	#	#
Fire Monitor	Herd oil	1	2	2-4 hours	<1 hour

depends upon location

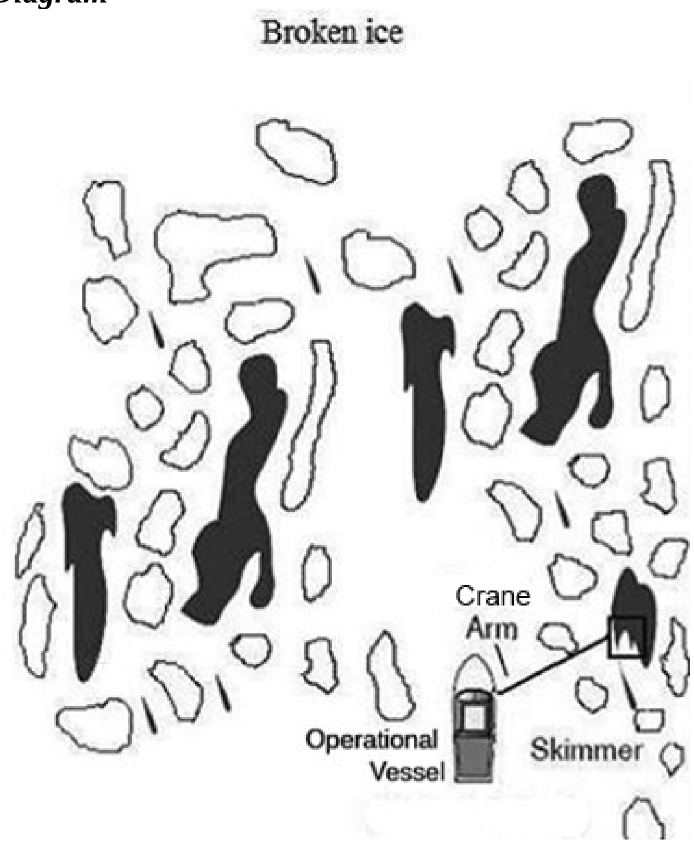
Broken Ice Conditions – Large and Small Pockets

Ice floe shapes are widely unpredictable in an ice field so when an oil spill occurs, one may face large and small pockets of oil. The vessel would need to maneuver its way through the ice field and determine if the skimmer can remove the oil in the areas between the ice pieces.

Deployment Considerations and Limitations

The vessel chosen should have the appropriate ice classification and manning to perform this. Selection of the appropriate skimmer is the key for this tactic. Temporary storage should be addressed. Vessel may not be able to maneuver if the barge is tied alongside. Adequate water supply tanks, hoses, and heating systems may be needed on certain configurations. Long lengths of hose running over the deck may need to be heated to prevent freezing. Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs. The use of an oil recovery bucket/boom assembly securely mounted to the deck of a barge and pushed by a towboat works well in these circumstances in terms of maneuverability. Comparatively, skimmers that use a tether system and that are deployed over the side may present challenges in terms of maneuverability.

Tactic Diagram



Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Operational Vessel	Working platform	1	4-8	#	#
Tugboat	Working platform	1	#	#	#
Skimmer	Recovery	1-2	2-4	#	1-2 hours

depends upon location

Broken Ice Conditions – Slotting

Oil moving under ice that is thick enough for personnel and equipment can be concentrated in slots cut in the ice and recovered by skimming with rope mops or other types of skimmers. If the oil is thick enough, it can be removed using direct suction.

Deployment Considerations and Limitations

In broken ice conditions, ice that is moved aside may shift back into place depending upon wind and wave conditions. The window of operations may be limited. Shifting ice can easily entrain the oil under the ice so caution should be taken not to disturb the ice.

Permitting Oil to Surface and Pool for Easier Collection

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Ice-capable Vessel	Equipment transport	1	#	#	#
Ice Auger/ Chain Saw	Recovery hole	2-3	#	#	#
Skimmer	Recovery	1-3	#	#	#
Generator	Skimmer power	1-2	#	#	#

depends upon location

4. UNDER ICE SHEET CONDITIONS (SHORELINE ONLY)

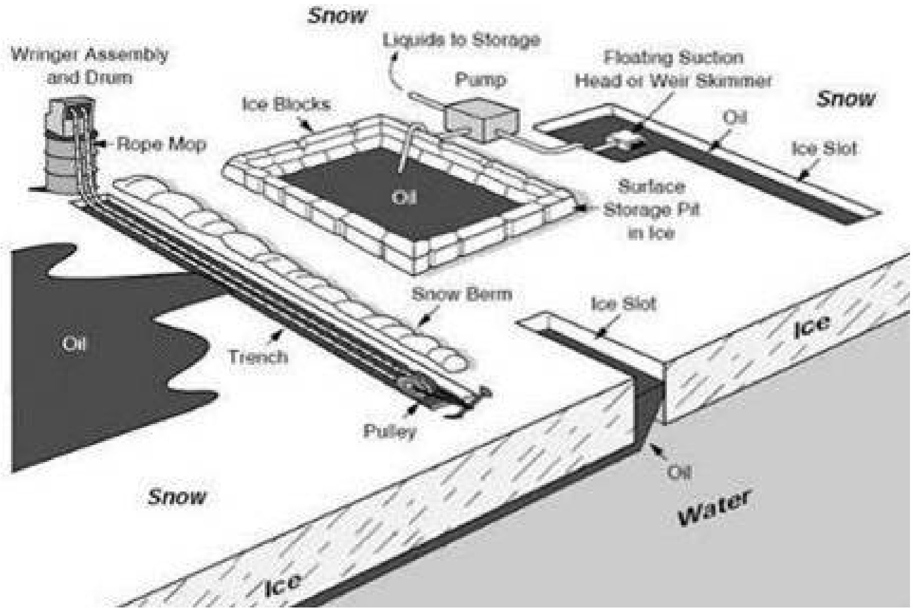
Under Ice Sheet Conditions – Collection Pockets

Oil entrained in subsurface pockets can be reached by drilling holes with ice augers and pumping the oil directly to storage containers such as drums or bladders. It can be further separated or burned in a location agreeable to all parties. This assumes that the ice is strong and stable enough to support personnel and equipment.

Deployment Considerations and Limitations

This tactic assumes that personnel and equipment can be deployed in a limited way near shore. The ice may support people and light equipment but not heavy hydraulics or vehicles. Depths should be limited to no more that 4-5' under the ice for safety in case someone breaks through. Full dry suits are usually required.

Collection Pockets: Methods of Establishing Oil Collection Pockets in Sheet Ice



Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	MOBE TIME	DEPLOY TIME
Vessel/Vehicle	Equipment transport	1-4	1	#	#
Ice Auger/ Chain Saw	Recovery hole	1-4	4-6	#	#
Skimmer	Recovery	1-2	2-4	#	#
Generator/ Hydraulic Powerpack	Skimmer power	1-2	#	#	#

depends upon location